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MIDDLE FRIO SAND
IN WEST COLUMBIA FIELD
BRAZORIA COUNTY, TEXAS

Mud (Aquagel and Phosphate): R_m = 1.00 ohm at BHT
Bit Size: 9⅞"
Spacings: AM = 16'
AM' = 63'
AO = 19'

This is another in a series of interpreted electrical logs from identified formations and fields which Schlumberger will reproduce in this publication. If you would like to keep this entire series, please write to us on your letterhead and we will be glad to send you a reprint of this log (and preceding logs in this series) with a binder in which you may file subsequent logs as they are published. This series is made possible through the courtesy and cooperation of the oil operators who have released these logs.

6

LOG ANALYSIS

1) Water saturation S

At water level $R_o = 0.3$ ohms

At level A, $S = \sqrt{\frac{.3}{21}} = 12\%$ approx.

2) Formation water resistivity R_w

$SP = -70 \log_{10} \frac{R_e}{R_w} = -90$ mv.,

thus, $R_w = 0.05$ ohm at BHT

3) Porosity p

$F = \frac{R_o}{R_w} = \frac{0.3}{0.05} = 6$

$p = \sqrt[m]{\frac{1}{F}} = 30\%$ for $m = 1.5$

CORE ANALYSIS

Average Porosity	30%
Average Permeability	1000 md.
Residual water	45%

Connate water determined by restored state methods 10-12%

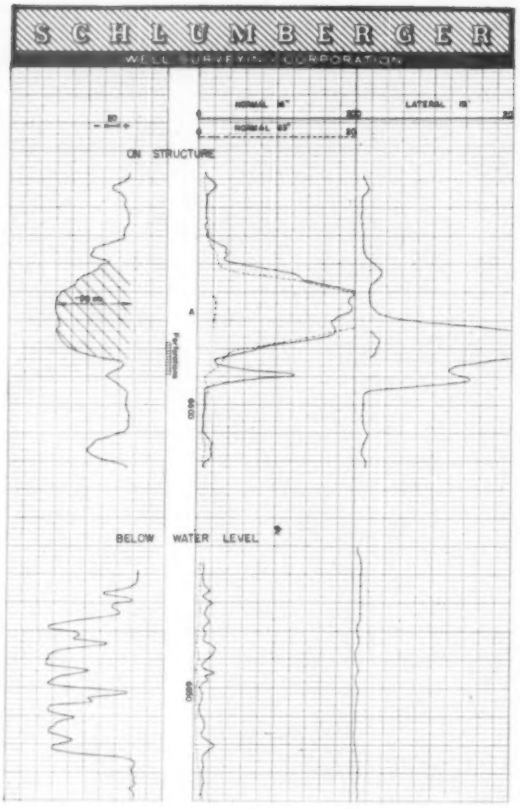
PRODUCTION RESULTS

Perforated: 6581-6594

Initial Production: 97 bbls. per day 30° API

Gas oil ratio: 4400/1

Gas increasing with time.



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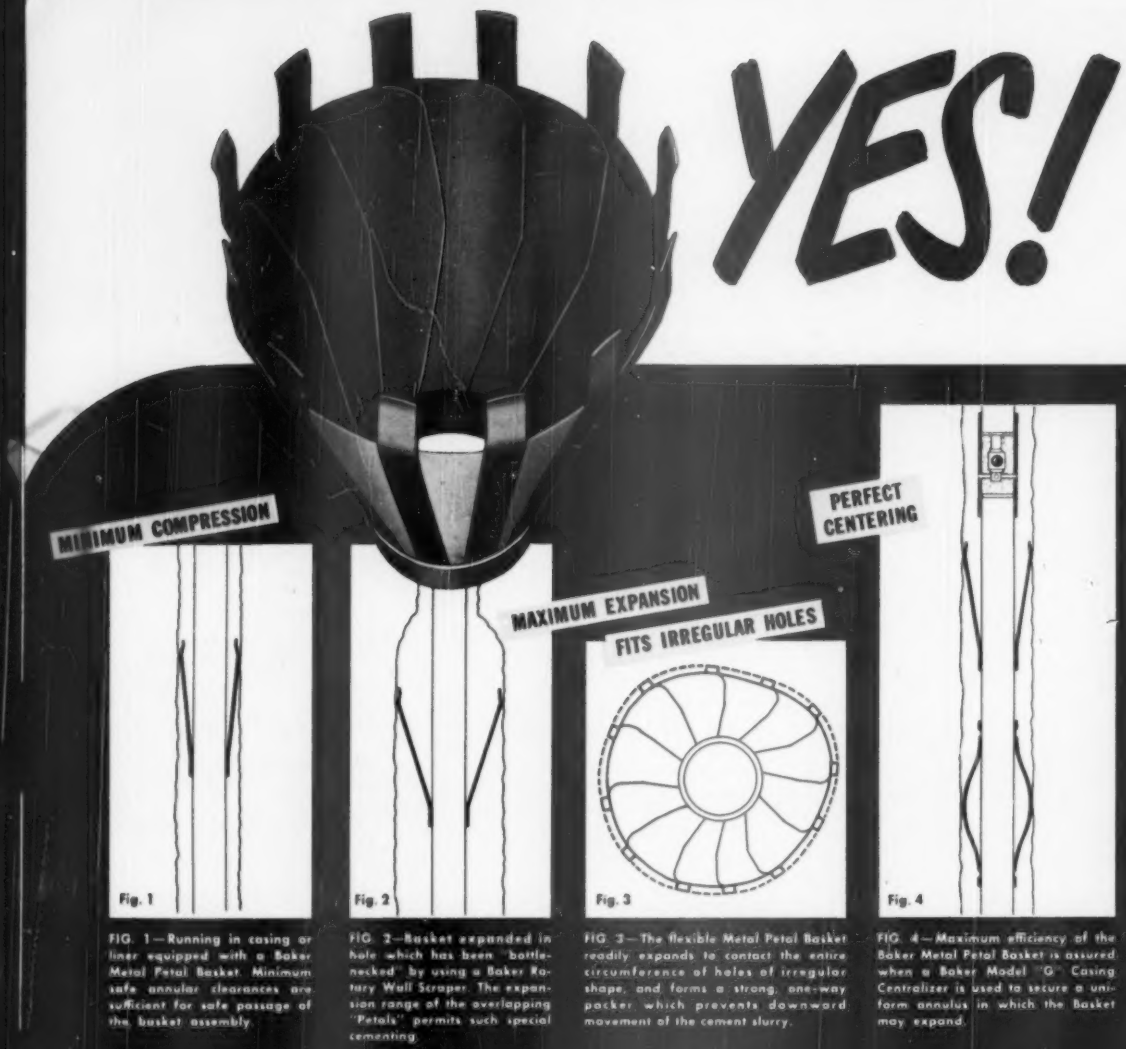

FIG. 1—Running in casing or liner equipped with a Baker Metal Petal Basket. Minimum safe annular clearances are sufficient for safe passage of the basket assembly.

FIG. 2—Basket expanded in hole which has been "bottle-necked" by using a Baker Rotary Wall Scraper. The expansion range of the overlapping "Petals" permits such special cementing.

FIG. 3—The flexible Metal Petal Basket readily expands to contact the entire circumference of holes of irregular shape, and forms a strong, one-way packer which prevents downward movement of the cement slurry.

FIG. 4—Maximum efficiency of the Baker Metal Petal Basket is assured when a Baker Model "G" Casing Centralizer is used to secure a uniform annulus in which the Basket may expand.

FOR any cementing problem where a lower zone must be protected from contamination by the cement slurry (as well as from sloughings or cavings) the Baker METAL PETAL Basket will be found both safe and successful.

The unit is constructed of a number of individual "petals" made of flexible sheet metal. These petals are mounted on reinforcing spring steel ribs, which in turn are mounted on a ring to form the Basket. The all-metal construction and design provide ample strength; lessen the possibility of splitting or otherwise damaging the Basket while it is being run in the well; and the metals used are unaffected by the usual acids employed for various purposes.

When running in the hole, the upward pressure of the fluid tends to close the "petals" thus providing fluid passageway between the Basket and the walls of the hole, without distortion of the Basket. As soon as the casing comes to rest, upward pressure by the fluid is relieved and the petals expand to contact the walls of the hole. Any tendency of the fluid to move downward then presses the flexible petals more firmly against the entire circumference of the hole. Solids which are strained from the fluid tend to build a bridge inside the Basket which is thus converted into a one-way packer of great strength and effectiveness.

The "Metal Petals" not only expand to contact the entire circumference of large-diameter holes, but also pack-off in holes of irregular shape; and the independent action of the individually mounted, overlapping petals permits successful use of the Basket in casing programs with minimum clearances.

MOUNTINGS MEET ALL NEEDS

The Baker Metal Petal Basket is furnished as a separate unit for installation in the field on the customer's casing, either as a fixed unit or as a slidable unit (with the use of stop rings). When desired, the Baker Metal Petal Basket can be furnished affixed slidably or stationary on a plain or perforated nipple to meet the requirements of the cementing job to be performed.

For details see the BAKER (or Composite) CATALOG; or ask any Baker representative for specific recommendations on your cementing problems.

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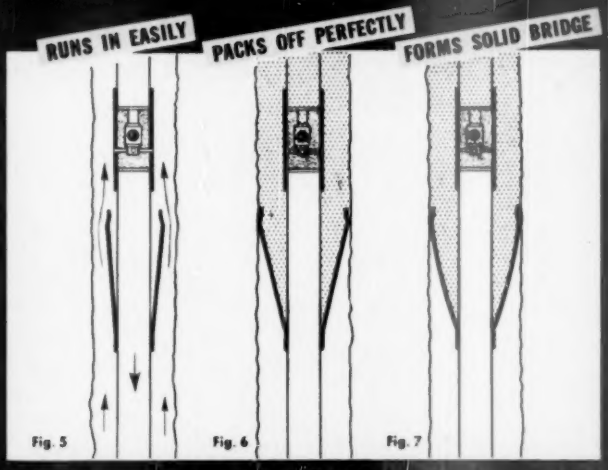

FIG. 5—When running pipe in the hole, the Metal Petals readily compress as the fluid exerts an upward pressure. Normal speed of running-in is maintained, and friction of the Basket assembly against the I.D. of the casing, or of the open hole, is avoided. FIG. 6—When the casing comes to rest, the Basket expands against the walls of the hole. Further downward passage of fluid from above is effectively minimized, until (FIG. 7) the solids strained out of the fluid build up a solid bridge inside the Basket, which then serves as a strong, safe, one-way packer.

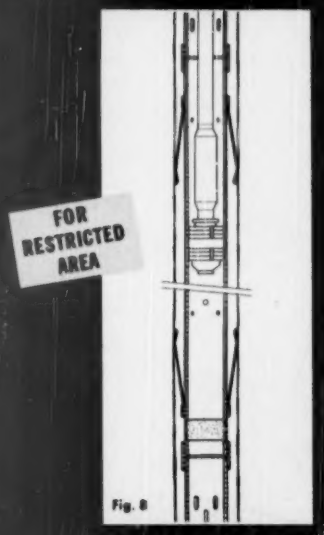

FIG. 8—By using a Baker INVERTED Metal Petal Basket, to provide an "opposed" basket hook-up, it is possible to perform special cementing operations, such as cementing a blank section of pipe, as shown above.

FIG. 9—A popular hook-up consists of a Baker Metal Petal Basket, mounted on nipple, with a Baker Cement Whirler Float Collar with Solid Baffle (Product No. 305) which causes the cement slurry to pass through the baffled, side-whirler ports.

FIG. 10—When the casing is to be rotated or reciprocated while cementing, the Metal Petal Basket is "slidably" mounted between two Stop Rings. This permits free rotation and ample vertical movement of the casing without distorting or damaging the Basket.

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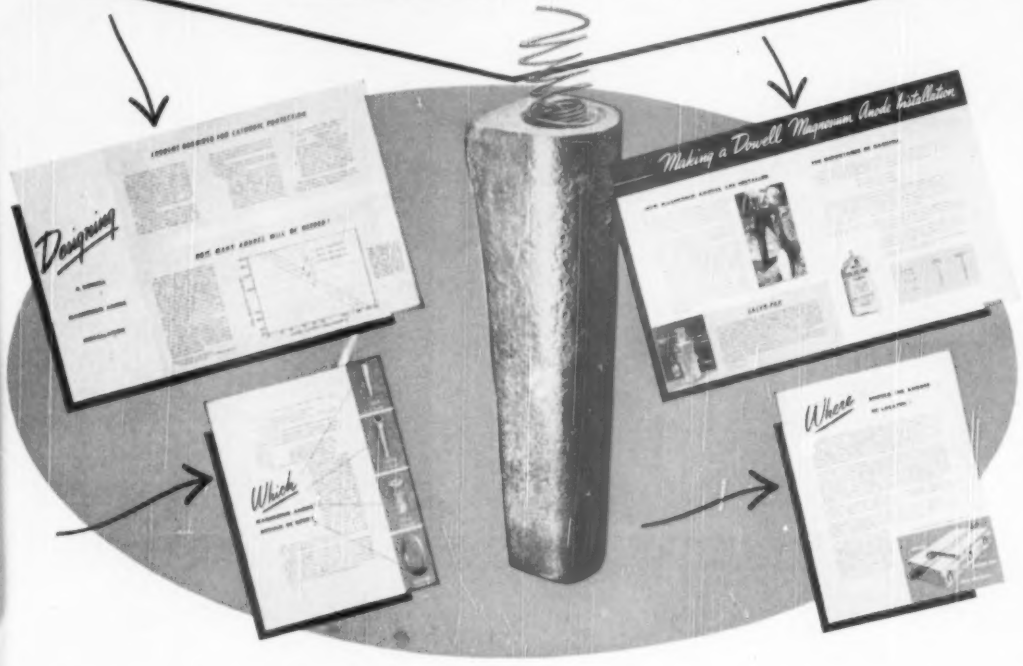

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MAGNESIUM ANODES FOR CORROSION CONTROL

Guest Editorial

By
W. H. Geis, Member AIME*
* Consulting Engineer,
Los Angeles

ENGINEER REGISTRATION AS THE LAW OF THE LAND

REGISTRATION of engineers is now required by law in every state of the Union and in the Territories of Puerto Rico, Hawaii, and Alaska. Congress will probably pass a registration law for the District of Columbia, following the more urgent national legislation. The universality of the requirement proves that there are fundamental reasons why engineers should be registered. These reasons are superior, in some measure, to personal views and rights, and therefore are resisted by the most individualistic.

However, it was society which found it necessary to regulate the performance of professional people whose activities materially affected the health, safety, property, comfort, and morals of the public. If all those who claim to be engineers were truly qualified, the need for registration would probably never have arisen. But the public, prior to registration, had no means of distinguishing the educated and/or the experienced engineers from those who misappropriated and abused both the title and the profession. Moreover, the public attached a confidence and respect to the title "Engineer" and relied upon the profession to safeguard its transcendent interests. Such confidence was merited by the ethical engineer, but nullified by the practices of the unethical, unscrupulous, incompetent, and downright quack, masquerading in an unprotected title which could be assumed or shed at will without responsibility.

The failure of structures, the insecurity of investments, the inadequacies of plans and designs, together with numerous dishonorable practices, which marked the activities of the unqualified, also constituted a form of competition with which the ethical elements of the profession could not easily cope. The success and safety of a thousand well-enginered programs were publicly overlooked in the glamorized failure of a single unengineered project. This was leading to disrepute of all engineering. The high standards of a worthy profession were so easily circumvented that a legal agency had to be established which could safeguard the public; and, if at the same time it lent protection to the competent engineer who had invested money and years in his training, so much the better. Registration was the agency selected. Some have called this "licensing," and although there are significant differences, the two words are sometimes used synonyms.

THE impact of engineering on the public welfare was recognized in the original Wyoming law adopted in 1907. Clarence Johnson, then State Engineer, drafted the first law and reported that the urgency therefor resulted from the design of water-use plans by those who had no engineering training. Wyoming is not a state which can afford to be profligate with its water resources, if in fact any state or nation can be. Let anyone who doubts this consider the situation on the West Coast where future aspirations are limited by the paucity of water resources, irrespective of other natural abundances.

Conservation does not imply limiting the use of a commodity, but rather, to so use it as to obtain the greatest possible utility. This requires sound engineering, whether or not it be civil, mechanical, electrical, chemical, or petroleum. Sound engineering, in turn, requires the exercise of professional talents and judgment by persons skilled in mathematics, with the ability to apply the sciences to the solution of a particular problem and to record the procedure by means of plans and specifications. These latter can be interpreted and executed by others endowed with trade and other skills which, when responsibly applied, eventually result in safely accomplishing the original purpose. It does not follow that the latter individuals are any less intelligent or able than the engineer. However, the one activity is engineering while the other is not.

Continued on Page 6

* Member of the California State Board of Registration for Civil and Professional Engineers.

From the Secretary

Since I am soon leaving the staff of the AIME to take up similar duties with the Division of Production of the American Petroleum Institute, in Dallas, I more than ever feel the need for some expression of my personal gratitude to the hundreds of you whose work with Local Sections, Branch Committees, Fall Meeting Committees; and as authors, discussers and reviewers of papers has made this position an enjoyable one for me. While this work you have done was for the AIME, with no thanks sought, it was done so often at my request that I feel entitled to say "thank you", from *me* to *you*, and apart from the AIME. I regret the rush of events left not enough time to acknowledge each instance of generous cooperation as it arose. The associations of the past four years have meant much to me. It has been a pleasure to move among you.

Bill Strang

Continued from Page 5

A line of demarcation should be drawn properly fixing the responsibility; firstly, for the plan and design; and secondly, for the execution thereof. In some cases the engineer may be responsible for both, but ordinarily the execution is a contracting function.

The classification of individuals, in accordance with their engineering training and ability, is accomplished under the various state laws by Boards of Registration, or Boards of Engineering Examiners. It is their responsibility to judge the qualifications of those claiming to be engineers. Registration of the qualified engineer only, eliminates the nonengineer from either engaging in the practice of engineering or in using the title "Engineer," thus removing the implication that the latter is qualified to perform engineering commitments.

The engineering boards have wide discretionary power, as well as great responsibility. They must be very vigilant to protect the interest of the general public in keeping with the specific law, so as to prevent the registration and the practice of engineering by those who are not competent. Equal vigilance and good judgment are also required so as not to make the qualifications too stringent. The boards' standards must be high, but not so high as to eliminate competition and turn engineering into a "closed-shop" proposition. This is one of the arguments sometimes directed against the idea of registration. However, it has been the writer's experience, after reviewing numerous examinations, that not one has been found where the questions were so difficult that a passing grade could not be obtained by anyone competent to take responsible charge of an engineering project in the same field as the examination. Naturally, a chemical, electrical, or petroleum engineer should not be required to pass an examination in structural engineering, or a structural engineer pass an examination in petroleum engineering. However, all engineers, in whatever branches, should be able to qualify in the basic fundamentals of engineering, since the fundamentals are the same in all branches.

MOST laws, in order to prevent undue hardship, and to provide a smooth period of transition from the unrestricted to the restricted use of titles, permitted registration, for a limited time, by a "Grandfather Clause." Under the Grandfather provision a qualified engineer could be registered without taking a written examination. In such cases, qualifications were determined by the boards on the basis of the applicant's past experience and accomplishments, plus a practical sponsorship by those who were familiar with the applicant's past work. Board records of the attempts of many applicants to support their qualifications, even under the liberalized Grandfather requirement, rather definitely proved the crying need for registration statutes if engineering was to continue as an honored profession.

The registration mortality in California under the very simple Frandfather Clause approached 20 per cent. Many board members will possibly agree that an additional 20 per cent of the applicants were able to obtain registration solely because they could meet the minimum statutory requirements; that is, the written word of the law, and not because of their retained fundamental engineering knowledge. However, many who might fall into the latter classification are specialists performing one restricted engineering function, and in most cases doing that one exceedingly well. As long as a registrant restricts his activities to the particular endeavor for which he is qualified, no harm is possibly done either to the public or to the profession. But the danger lies in the human urge, once the applicant has attained professional status and the bars are down, to engage in expanded engineering activities for which he definitely is not qualified.

Some who failed to qualify, and others, attacked the judgment of the boards, and advanced arguments and introduced bills into legislatures to prove that, after all, the public is not concerned with engineering, and that the requirement to register is simply a nuisance, accomplishing no useful purpose. Such arguments are easily refuted.

EVERYONE will admit that the age in which we live can be described as "high powered." There is no need to argue whether this is good or bad. The fact remains that this age accepts as normal the gigantic above-ground and underground structures of a modern city; the high speeds of the jet plane and the rocket; the engineered mysteries of radar, radio, television, and the mysteries of electronic devices; plus the cyclotron, betatron, and the implications of atomic energy. The public has every right to assume that the Frankensteinic possibilities of many of the things created by engineering skill must also be controlled by competent people capable of safeguarding the lives, property, and welfare of the public.

A public responsibility, therefore, attaches to the engineering profession, which has crystallized into laws intended to provide that the format, plans and specifications for the utilization and conservation of resources, with all the connotations involving the public safety in the design and use of structures and machines, in the broadest sense, must be prepared by professionals of recognized competence.

Consciously or unconsciously, the moral, physical, and financial investments of society in the thing which is called civilization, dictated that all professional people, not only those in medicine and law, should be subject to discipline initially taking the form of registration which provides a standard of comparison.

Some engineers of mature stature oppose registration, preferring to use the derogative term "regimentation." This position seems to be an emotional expression of self-satisfaction and a form of righteousness in resistance to law, which may differ in degree, but includes some elements of the insanity plea in the case of murder. Moreover, no one contends that the lawyers or medical doctors are regimented, although the latter, in some states, have been required to register for nearly 100 years. Other opponents claim that registration is not in the public interest, citing the case of petroleum engineering which they say does not affect the welfare, safety, happiness, or comfort of the public. This attitude indicates a rather immature understanding of the responsibilities of an engineer, and when expressed by one already in the profession is very apt to create doubt as to the individual's own personal standards, irrespective of how good an engineer he may be. In addition, the courts have already held that it is not the province of the individual to judge what is or is not in the public interest. Such is the function of a legislature which, when it speaks in

the passage of a law, exercises a superior judgment which the courts will sustain, unless the action of the legislature is determined to be capricious. Surely it cannot be successfully argued that the 48 legislatures, in passing engineering registration statutes, all acted capriciously.

THEN, there is the die-hard position that registration deprives a person of his right to work, as guaranteed by the Fifth and Fourteenth Amendments to the United States Constitution. These are the amendments which provide that "No person shall be deprived of life, liberty, or property, without due process of law." In this connection, a profession has been interpreted to be property, and the amendments have been construed as guaranteeing an individual's right to work. Somewhat in support of this position, the courts have ruled that there are occupations which in themselves are harmless and in which men have engaged immemorially as a "matter of common right," and that these occupations should not be surrounded with restrictions which bar an individual. Certainly, engineering has been practiced immemorially. However, these amendments, and all laws expressing similar security, do not permit people to engage in unlawful pursuits. If gangsterism is your occupation, your right to work at it is not only restricted, but you are put away for good. One may be licensed to sell liquor (quite different from registration), but the bootlegger goes to jail as a result of his persistence in such work. Accumulating gold used to be the favored work of many, but today you lose your liberty, and your property as well, if it is found in your possession. There are literally hundreds of pursuits essentially quite harmless in themselves but which have become unlawful because they adversely affect public interest. Even inanimate things, like automobiles, boats, airplanes, together with the operators, must be licensed or registered. The list may go on endlessly to include the butcher, the baker, and the candlestick maker.

The licensing, or registration, either of people or things, is an evidence of the police power of the state. The Constitution does not guarantee an individual the right to engage in any business, occupation or profession which injures the general public, or which injures a substantial group of the public. The right to work, lofty as that may sound, is subject in every case to reasonable regulation by the proper authority.

IT therefore follows that the state properly can demand evidence of one's definite skill before he may engage in a specific occupation. Such is the case with the airplane pilot. An inexperienced pilot is as dangerous to the public as a homicidal maniac. If skill is required in operating a machine, how much greater is the need for skill in the design of that machine. If the relationships are to be placed in their proper order, the machine itself must first be safe, and hence the designer-engineer is a prime candidate for licensing. Consequently, the right to work is subordinate to the superior right, and even the duty, of the state to exercise its police powers in protecting the public, even if thereby the rights of an individual are restricted.

Therefore, it is not accidental that engineer registration laws have been passed by all the states. The legislatures have stated, in effect, that engineering does affect the public welfare, and, since to be an engineer requires special training, the police power is invoked to assure that those engaged in professional engineering have the required training.

The basic requirements for registration cannot be considered as other than reasonable. First, the applicant must be of good moral character, a requirement with which no one could complain. Second, he must show evidence of sufficient engineering education obtained either in school, by self education, or through years of experience. Third, in addition to the educational requirement, he must have had the necessary practical experience. Following the termination of the Grandfather provision, some states require that an applicant must first pass a written examination in fundamental engineering. Then, with sufficient practical experience, he may take a second examination in the direct application of his particular profession. Having passed the first examination, and not being qualified to take the second, the status "Engineer-in-Training" may be granted. Under the Grandfather Clause, this status was automatically extended to graduates of accredited engineering schools.

UNFORTUNATELY, the laws of the various states are by no means uniform; neither are the standards as set up by the examining boards. The professional societies are quite conscious of this situation and are endeavoring to promote a "Model Law." This law has been approved and endorsed by the following:

American Institute of Electrical Engineers
American Society of Civil Engineers
American Society of Mechanical Engineers
American Association of Engineers
American Institute of Consulting Engineers
National Society of Professional Engineers
National Council of State Boards of Engineering Examiners
American Society of Heating and Ventilating Engineers
American Institute of Mining and Metallurgical Engineers
Illuminating Engineering Society
Society of Naval Architects and Marine Engineers
American Institute of Chemical Engineers
American Society for Engineering Education (formerly Society for the Promotion of Engineering Education)

In conclusion, those now studying engineering, as well as many who have not applied for registration, should realize that the 48 states, and the Territories, have statutes covering registration. Consequently, registration is truly the "Law of the Land," and since 13 professional societies have approved a law, registration is also the "Law of the Professions." Undoubtedly, registration of engineers is here to stay, and as time goes on the education and experience requirements are quite apt to become more and more stringent.

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John L. Waddleton. "Licensing for the Engineering Profession," *American Society for Engineering Education*, Rensselaer Polytechnic Institute, June 20, 1949. ★ ★ ★

JOHN E. SHERBORNE

Petroleum Branch Chairman 1950

FROM talking to him you wouldn't realize that John Sherborne is a native Englishman. But upon being asked he will tell you, in his unassuming way, that his first residence was established at Leeds in Yorkshire in 1911. After the young years, he came with his parents to the United States in 1920, and the family settled in Southern California. He became a citizen of the U. S. in 1926, and was graduated from high school at Long Beach.

An early interest in things scientific developed from watching the nearby oilfields, and as the turbulent thirties began he entered California Institute of Technology. Diligent study occupied his time in college, with varied jobs on the side. Illustrative of his patient determination was the job he took after the Long Beach earthquake in 1933 — he cleaned thousands of bricks from fallen buildings with a mortar trowel to add to his college fund. He was rewarded by a B. Sc. degree from Cal Tech in 1934. This did not satisfy his desire for education, and with his interest in oil firmly established, he went on to receive a M. Sc. in petroleum engineering from the University of Southern California.

John joined the Union Oil Co. of California in 1936, as an apprentice engineer. All of his business life since has been with Union, and in October, 1949, he was made assistant to the vice president in charge of research. In between he has held a series of highly responsible positions. Until 1940 he worked in research and in production engineering; from then until 1944 he served as a process engineer in charge of those phases having to do with oil and water gathering and handling, dehydration, water disposal and water treatment. In 1945 he was made division production engineer; in January, 1948, he was promoted to chief production research engineer; and in August of 1948 he was made chief production engineer. In his early years with Union, John designed and built an apparatus for improvement of core analysis technique, and the company's core work has been outstanding since then.

IN 1937 John and Miss Dorothy Thompson were married, and they now have three boys whose ages are approximately five, three and two. Before the children, the two of them would often take sleeping bags and go into the mountains or the deserts to hunt rocks and hike in pursuit of his hobby of mineralogy. Boating, fishing, photography and mountaineering are also hobbies that occupy some of his now scarce spare time. One would never guess it, but he is almost a professional glass blower, having learned the technique at Cal Tech while working in chemical engineering. From 1940 until 1947 he served as a member of the petroleum engineering staff of the University of Southern California, conducting evening classes in various phases of petroleum production and reservoir engineering.

John has taken an active part in AIME activities since becoming a member in 1938. Among the Petroleum Branch committees on which he has served are the Membership, and Engineering Research, of which he was chairman from 1946 through 1948. Since 1946 he has been a member of the Branch Executive Committee, and he served as vice chairman of the Branch in 1949. In 1949 he also served as chairman of the Production Technology Committee, this committee being responsible for the programs at the Branch Fall Meetings.

DESPITE the heavy load of all these activities in previous years, John has been very active in other organizations. He has served on several API committees; from 1941 to 1943 he was national chairman of the Subcommittee on Core Analysis and Electric Logging; and from 1944 to 1945 he was national chairman of the Topical Committee on Production Technology. He is also an active member of Sigma Xi, the AAPG, and the AIChE.

A thorough swabbing of his close associates produces only high gravity information on John. He is a soft spoken, completely self-effacing man who does not seek attention but gains it through his ability and efficiency. He is well known and universally liked in the industry and profession, and the Branch can look forward to capable guidance by him during the ensuing year. ★ ★ ★

Aerial Photogrammetry

As Applied to the Petroleum Industry

By Louis A. Woodward, Jack Ammann Photogrammetric Engineers, San Antonio, Texas

To a great many people, a map is something you get with a tank of gasoline at the corner filling station. However, if you are faced with the problem of locating and building an access road to a well location several miles back in the mountains, or locating and building a pipe line from here to Albuquerque or Los Angeles; the road map obtained from the filling station will be of little or no value. A different type of map is required for this purpose, one showing all cultural, drainage features, and contours, supplemented with aerial photographs and possibly an aerial photographic mosaic would be of material assistance. With such map information your job of locating the road or pipe line would be greatly simplified, the job could be completed much more rapidly and for considerably less money.

Many people representing both large and small organizations either do not recognize the value of adequate map information or do not know how cheaply map information may be obtained in relation to costs that will otherwise be incurred. For example consider a small company drilling a wildcat well in Bandera County, Texas, several miles from the closest federal, state, or county road and the number of people that will have to visit this well before the "bottom of the hole" is reached. To reach the location one might be given a description such as "take highway number 90 west from Uvalde about three miles to the second gate beyond the creek . . . turn right through the gate and go about three miles to a road fork . . . take the left hand fork until you cross the second creek . . . then follow the creek upstream about one mile and" . . . by this time you are half way to the well location and most of the people having occasion to go there are lost.

If aerial photographs of the location

Fig. 1 — Photograph of an area of Wyoming shows at a glance all phases of the oil business. A closed structure appears on the lower portion, several oil wells in the center, a refinery at the top, and tank cars and pipelines in the middle.

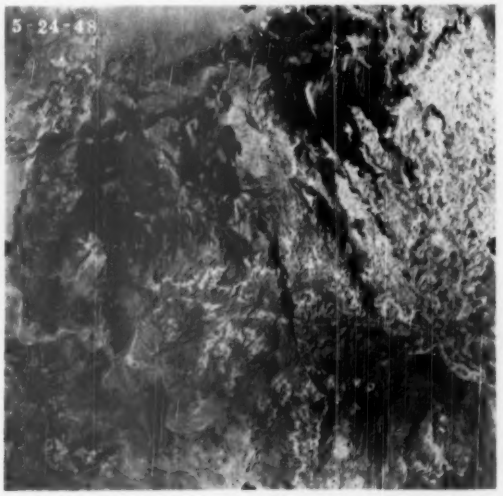

Fig. 2 — Photograph shows two geological features at a glance, namely a dike cutting across a fault. This inaccessible area is in South Central Utah.

and surrounding area served no other purpose than keeping these people from geting lost they would more than pay for themselves.

We in aerial photogrammetry must determine and demonstrate how our products can serve to further the interests of various fields of endeavor. We have found many ways of assisting organizations primarily interested in exploration and development work. In the petroleum industry geologists are the largest users of aerial photogrammetric materials. A geologist friend of mine explains this by claiming that the average geologist is not lazy but is very ingenious in finding ways to do his work without using any more physical energy than absolutely necessary. It was found that aerial photography not only simplified field geology but that many structures and other features could be quickly found on the photographs that could not first be found on the ground. In most cases aerial photography alone will not locate oil wells, however they will show the geologist which areas are the most promising and must be worked on the ground and also which areas are of little or no importance.

For photo-geology an aerial negative scale of 1:20,000 obtained with a precision camera having a focal lens of 8¼ in. or longer has proven to be most satisfactory. For other purposes different camera, scales and flight heights are required. Within the past year we have flown jobs as low as 800 ft and as high as 32,000 ft or six miles above sea level. To obtain photography such as required by the geologist, the plane flies parallel strips two miles apart at an altiude of about 13,750 ft above mean ground level. Exposures along each flight are taken at intervals of about one mile. Thus, the adjacent strips of photographs will overlap about 30 per cent and the adjacent photographs in line of flight will overlap about 60 per cent. This method of flying assures that every part of the area will appear on at least two photographs taken from different air positions.

The maximum value cannot be derived from aerial photographs without the aid of a stereoscope. By properly placing two photographs of the same area under a stereoscope it is easily pos-

Fig. 3 — A few of the various types of cameras necessary to meet current aerial photogrammetric requirements. Cameras having focal lengths from 5 in. to 24 in. are frequently required.

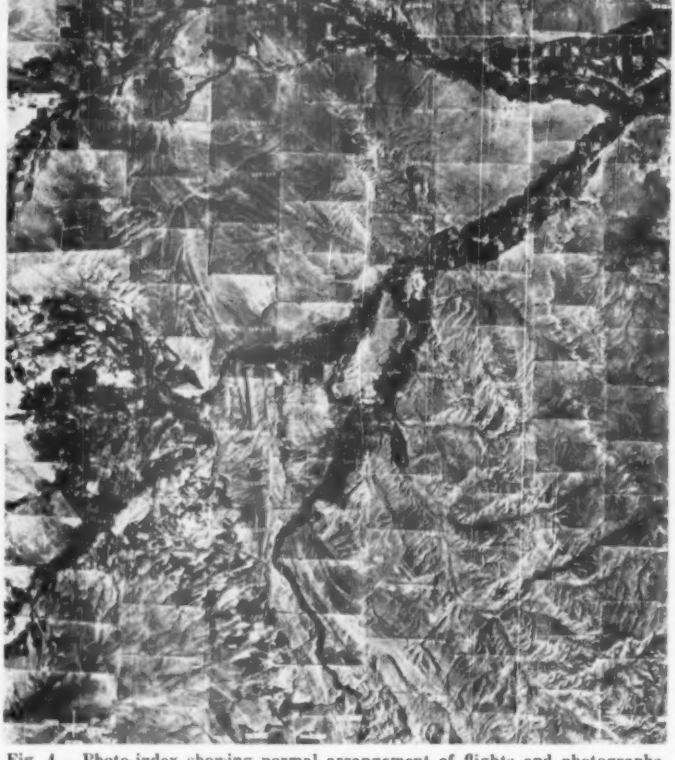

Fig. 4 — Photo-index showing normal arrangement of flights and photographs. Area is near Lander, Wyoming.

Fig. 6 — Mosaic of an area comprising approximately 40,000 acres in Wyoming was compiled from 36 aerial photographs. The net area covered by a single photograph is outlined.

sible to view and study the area in the third dimension. Relative heights of hills, depths of canyons and slopes of terrain, etc., are easily determined. Not more than 50 per cent of the value contained in aerial photographs can be obtained without the aid of a stereoscope.

In many cases a mosaic or photo map compiled from a group of photographs to give a composite photograph of a

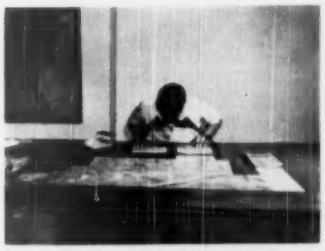

Fig. 5 — Mirror and di-optic lens type stereoscopes most commonly used.

Fig. 7 — Section of an 800-mi. pipe line mosaic. The mosaic was used for locating the line, acquisition of right-of-way, computing the amount of pipe and where pipe could best be stockpiled to be readily available for construction crews, for locating pumping stations, and for many other purposes.

larger areas is very helpful. Except when the area of interest is small, such as a complete structure appearing on a single photograph, a much better overall appreciation of an area can be obtained from the mosaic than from the individual photographs. Generally, a stereoscopic study of the individual photographs together with a mosaic of the entire area under consideration will disclose the most information.

No single photograph would have depicted the complete story of the area shown in Fig. 6 as was the case in Fig. 1 and 2. By the proper application of photogrammetric methods, equipment and materials, aerial mosaics can be made to appear as one large photograph. Only the center portion of the photographs are used in compiling such mosaics. Measurements made on properly compiled mosaics will be considerably more reliable than those made on contact prints.

Aerial photographs and mosaics supplemented by topographic maps of critical areas have been found very useful in connection with pipe line location and maintenance. After the general location of the line has been made a strip of photographs and a mosaic sufficiently wide to cover all possible final locations will go a long way toward making the best and cheapest location. The topographic maps of critical points such as river crossings and mountainous areas give advance information on construction problems at such points and permit proper planning. Such materials are also very helpful in dispatching the proper equipment and personnel to promptly fix breaks in the line.

The geologist in his never ending search for ways of doing geology with a minimum expenditure of physical energy and the aerial photogrammetrist soon got together on another type of work. By using photogrammetric equipment and only a few random field survey points it was demonstrated that the aerial photogrammetrist could determine elevations of any point required by the geologist. With elevations of all points desired, the geologist found that a very substantial part of the geology of an area can be completed in the office in a very short period of time and that field work was reduced to a minimum.

On January 6, 1949, we photographed an area of 368 square miles and delivered the photographs complete with 5,212 elevations on March 24, 1949. The

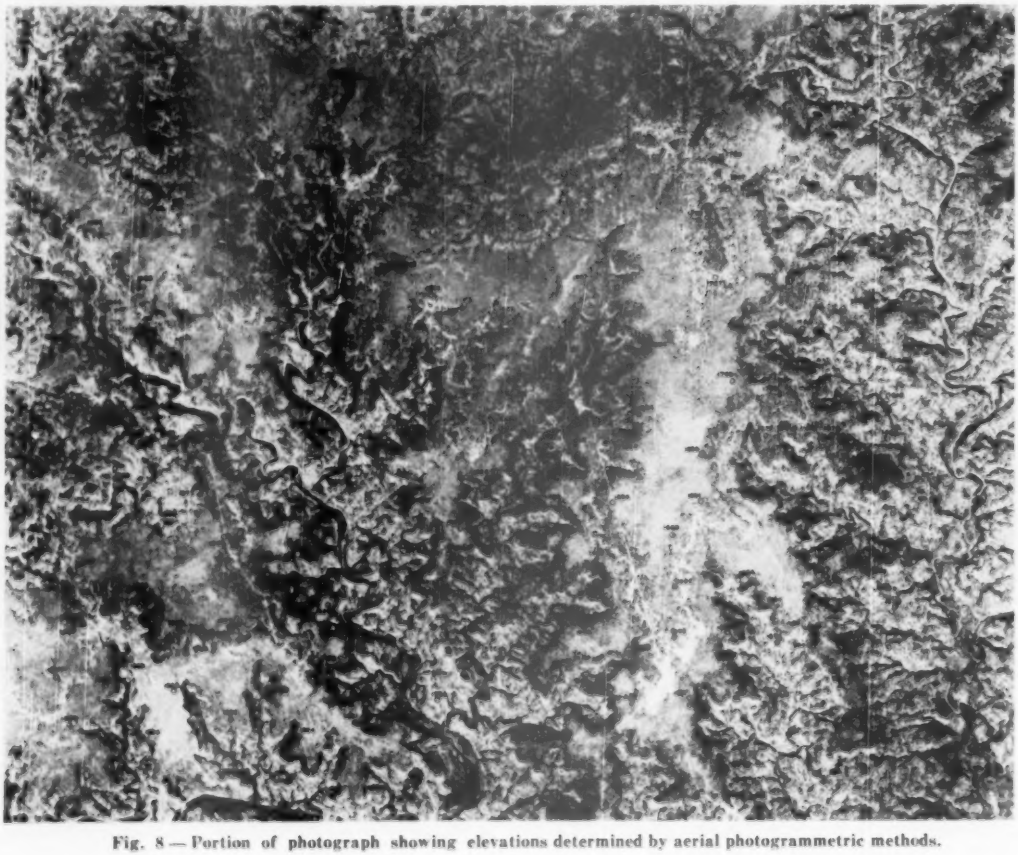

Fig. 8 — Portion of photograph showing elevations determined by aerial photogrammetric methods.

area had a range in elevations of about 500 ft and was typical inaccessible canyon country. The geologist required the elevations of the 5,212 points be correct within plus or minus 5 ft so that very accurate structural contours could be drawn. After the structural contours had been delineated on the individual photographs they were transferred to a composite mosaic of the area at a scale of 1-in. to 4,000 ft. A total elapsed time of 79 calendar days were required to complete the project. During this entire period favorable weather prevailed less than 40 days.

This method of combining the specialties of the photo-geologist and aerial photogrammetrist are a necessity in areas where a land owner will not allow a geologist or seismograph crew in the area prior to a lease agreement. With survey control along roads and railroads the aerial photogrammetrist can in most areas determine elevations of any point between and the photo geologist can thus determine whether the price of a lease agreement is a good investment.

Too many people are familiar with only the small scale large contour interval topographic maps that are produced by agencies of the government. Most of these maps are at a scale of either 1 in = 1 mi. or 2 in = 1 mi. with contour intervals of from 20 to 50 ft. For reconnaissance and other general map uses these maps are quite satisfactory, however since most operating organizations require large scale detailed information, the government maps have been found to be of little or no value for development work. In order to know exactly what conditions are going to be encountered on the ground large scales and small contour intervals are necessary. During the past few years we have been called upon to make topographic maps at scales from as large as 1 in. = 40 ft showing 1 ft contours down to 1 in. = 400 ft showing 10 ft contours. The cost of a topographic map compiled by photogrammetric methods seldom exceeds 60 per cent of the cost of such maps when plane table methods are used. Maps produced by photogrammetric methods are generally considerably more accurate and complete than those produced by ground methods.

It has been found that the Multiplex stereo-photogrammetric equipment as

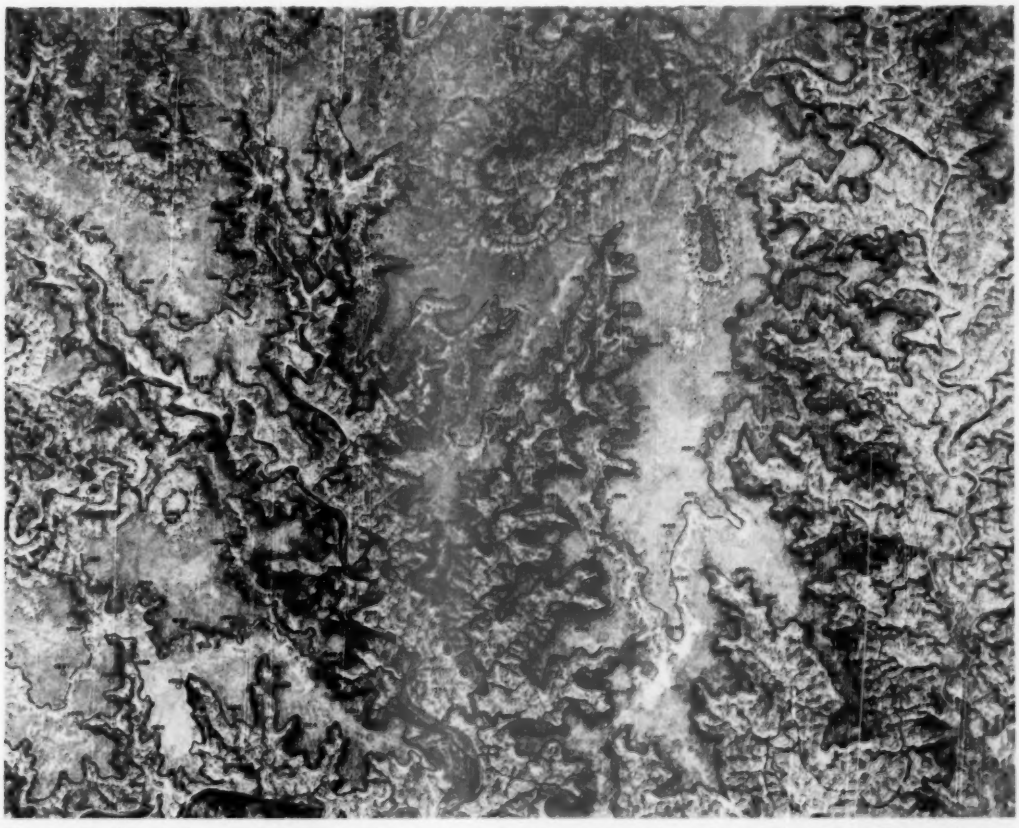

Fig. 9 — Portion of photograph shown in Fig. 8 with structural contours as drawn by a photogeologist. These structural contours are based entirely on the elevations determined by the aerial photogrammetrist and data interpreted from the aerial photographs by the geologist.

manufactured by the Bausch and Lomb Optical Co. is most suitable for topographic mapping. The first operation is to obtain photographs of the area in question. Second it is necessary to determine what field survey work is necessary and establish and identify the necessary survey points on the photographs.

The aerial photographic image is transferred as a diapositive to 64 mm. x 64 mm. glass plates which are placed in the projectors shown in Fig. 11. Each projector represents the position of the airplane as the exposures were made along the flight line. The operators of this equipment wear glasses with one blue and one red lens. Alternate blue and red filters are placed in the projectors. The glasses worn by the operator filter the projected images so that each eye independently views an image of the same area taken from different air stations. The brain resolves the minute differences between the two images into terms of depth or the third dimension, and with the plotting table it is possible to measure in this dimension. With horizontal control within the overlapping area of the two projectors on each end of the bar and elevations scattered along the flight, it is possible to adjust the projectors to give a scale model of the area covered by the entire flight of photographs. After the adjustment is completed, aerial control points are plotted within the overlapping area covered by each pair of projectors. The control for two flights are worked on one large sheet of paper and after this operation is comlete the large sheets are cut into smaller sheets and transferred into plotting rooms where the topographic maps are drawn.

The Multiplex plotting equipment, using the control established by the bridging operation is used to draw topographic maps or read elevations as required by the geologist.

Topographic maps as produced by aerial photogrammetry are finding many additional uses by the petroleum industry. They have been extremely valuable in connection with oil field development. Two topographic maps recently compiled, one for Standard of Texas of their Scurry County field in West Texas, and the other for General Petroleum of their Worland field in Wyoming have been of material value to these companies. These maps have been effectively used in overall planning and of particular value in making final well locations. The best acreage-well pattern placed a number of wells at unfavorable locations, such as steep hill sides and flat stream beds that were subject to flash floods. This was immediately noted on the topographic map and plans made to locate these wells at more favorable locations and use directional drilling to put the bottom of the hole where desired. Such maps have been found valuable in locating access roads, gathering systems and recycling plants. It has been possible to locate tanks and pipe lines connecting wells and tanks so that most of the oil can be collected by gravity flow, thus saving expensive pumping operations. Plants have been laid out and expanded on the basis of these reliable maps, water systems laid out and constructed, warehouses located to be most accessible for all operations and the best locations determined for lease houses.

There are four basic types of maps. They are aerial photographs, aerial photographic mosaics, planimetric, and topographic maps. We call such maps "base maps" as they are used as a base upon which special purpose data and plans may be plotted to enable the map user to arrive at conclusions pertinent to the subject of his study. Such data may be geologic, ownership data, development plans, road location, pipe line locations, tank locations, and many others all of which have a special purpose and are necessary for efficient operations.

The above mentioned four basic types of map may again be subdivided into two groups, one of which shows the map

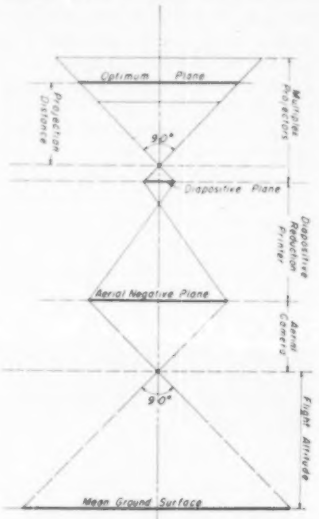

Fig. 10 — Diagram of Multiplex principle. The ground image is recorded through an aerial camera on to low shrink base aerial film, transferred to glass positives and then projected to scale on the Multiplex plotting table.

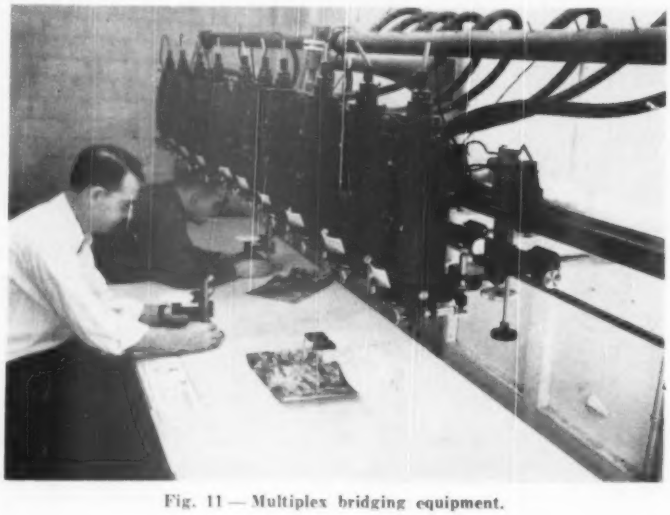

Fig. 11 — Multiplex bridging equipment.

information by a photographic image while the second shows such information by lines and symbols. Because of the inherent errors in the aerial photographic image it is possible to prepare the line and symbol type of map to a much higher degree acuracy. Maps prepared by lines and symbols all have the same general appearance and may be compiled by variety of methods each of which will produce a map of different quality. In maps like all other items a purchaser received about what he pays for provided the purchase price reflects the cost of production. A map cheaply compiled and containing numerous gross errors can be made to appear as neat, legible, and artistic as one compiled by sound engineering methods. However a small map user who utilizes a map to maximum advantage will soon discover the difference. For example try laying out a gravity flow system on an inaccurate map sometime and see how it works.

Fig. 12 — Multiplex Plotting.

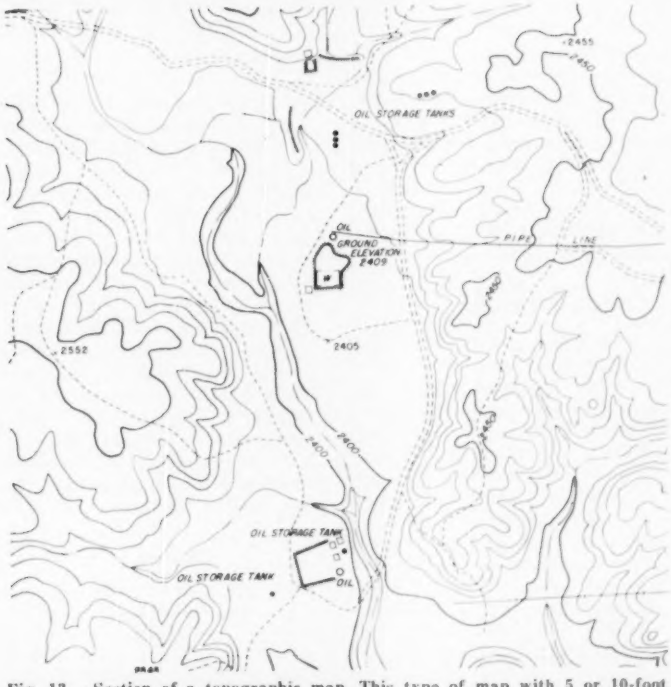

Fig. 13 — Section of a topographic map. This type of map with 5 or 10-foot contours at scales from 1 in. = 200 ft. to 1 in. = 400 ft. have been used very effectively in oil field development. For large plant sites 1-ft. and 2-ft. contours at larger scales are more satisfactory.

Dollar for dollar, the most and best map information will be obtained if map needs are anticipated in advance of the date the maps are actually needed. Map requirements should be thoroughly analyzed before a decision is made to procure any type of maps, and considerable thought should be given to eventual, or over-all needs, rather than to immediate needs alone. It is far more economical to originally spend a thousand dollars for maps that will meet all requirements, than to spend six or seven hundred dollars three or four times to meet immediate needs. I cannot overstress the importance of accurate up-to-date information. I know of one organization that recently purchased a set of existing aerial photographs taken some 10 years ago rather than to have new ones made for a pipe line location and thus saved a few hundred dollars at this point. However the location selected on the old photographs was found to go through an airport, several new subdivisions and an Army base, all of which were established since the photographs were made. The cost of relocation at these points far exceeded the amount saved by purchasing the old photographs.

In closing I would recommend that when a map problem arises that it be discussed with an engineer specializing in mapping. Ask for recommendations as to the type of photographs and maps most suitable for this purpose. I am sure that the end result will be maps that will meet the stated requirements at a cost considerably less than if produced by competent civil, mechanical, petroleum or other engineers who have a general knowledge of mapping but who have devoted the majority of their time and effort to specialization in other fields. ★ ★ ★

Associate in Arts in Petroleum Technology: A New Approach to Formalized Training for the Petroleum Industry

By JOHN O. NIGRA, Member AIME
Head of Department of Petroleum Technology
Orange Coast College, California

EDITOR'S NOTE: This description of the junior college training of technicians for the petroleum industry was condensed from a paper prepared by John O. Nigra, member AIME. It is published in the hope that it will provoke comment, for publication, on the value to the industry, or the profession, of two years of technical training for individuals working in the industry. This condensation excludes many of Nigra's explanations of the Orange Coast method of conducting sub-professional training, and the need for such training.

Introduction

A need is being recognized for the training of technicians for the petroleum industry on the junior college level instead of in the conventional four and five-year university pattern. This need is expressing itself in the establishment of petroleum technology courses and departments in a small number of junior colleges.

The latest addition to these institutions is Orange Coast College, located in Costa Mesa, Orange County, California, not far from the Newport and Huntington Beach oil fields. This school opened its doors in September, 1948. From the first it was able to plan an offering of terminal education courses in such fields as petroleum technology, agricultural technology, building trades, metal trades, engine mechanics as well as the business administration divisions of merchandising, secretarial training and accounting.

The petroleum technology curriculum was planned and organized by the writer after months of research and consultation with interested committees representing the oil industry in southern California. Preparation of course syllabi was aided materially by the California plan for vocational education as outlined by the California State Department of Education, and by the American Petroleum Institute outline for vocational training. In the second year of the petroleum major it was found expedient to introduce a few changes in the curriculum, making the courses more functional and flexible.

Advantages

The aims of the petroleum technology major are to prepare, not engineers, but technically trained personnel able to fit in time into sub-professional and supervisory jobs in the oil industry. This is in line with the general objectives of terminal education in the junior college. Students who have undergone this training will have acquired a theoretical and functional understanding of the fundamentals of oil field development and exploitation. They will have the advantage over those students enrolled in the conventional petroleum engineering training in that they will have covered the same basic subject matter (bereft of frills) and will be ready to occupy their places in industry four semesters sooner. This head-start will enable them to adjust themselves to the job: they will have the opportunity of becoming acquainted with their bosses, of learning the table of organization of their departments and related ones, of gaining an earlier insight into company policy and techniques; and they will acquire the spirit of loyalty to employer that comes only with time on the job. These advantages for the technical four semester college graduate might well offset the disadvantages of having gained a less complete (but no less integrated) type of education that their university brethren might have. At any rate, the disparity would require many years to prove and, in the mean time, the earlier graduate would be well financially ahead of his eight-semester cousin.

Objectives

The petroleum curriculum offered at Orange Coast College comprises four semesters. On completion the student is granted the Associate in Arts in Petroleum Technology degree. The technical course work is supplemented throughout its entirety with integrated courses

in the humanities such as English, history, psychology and hygiene.

Organization

The flexibility of the curriculum is best attested to by the number of elective units, seventeen in all, as shown in Tables I-A and I-B. Nineteen units of the total 64 (representing roughly one out of the four required semesters) are for courses in the humanities. American Petroleum Institute and American Association of Oilwell Drilling Contractors sponsored manuals prepared both by the University of Texas and Oklahoma A & M College are used as texts wherever applicable.

It will be noted that all phases of the petroleum industry are touched on, including exploration, development, exploitation, and refining. Drilling and production practices are emphasized, however, because it is in these areas that the greatest employment possibilities exist for the graduate. Direct donation or loan of mechanical equipment and supplies has made possible to afford class room and lab demonstrations of bits, pumps, tool joints, valves, fittings, sucker rods, drilling fluid chemical additives, etc.

A night school is a constituted part of the junior college program which is set up to fulfill community and industrial requirements for adult education in technical as well as cultural fields, relieving surrounding industries in many instances of the necessity of instituting, staffing and presenting their own costly on-the-job program. The possibility of offering actual training in such skills as drilling, well-pulling, still operation, etc., on the campus, however, is now prohibited by cost.

Evaluation

Like the few other curricula of similar nature being offered in different parts of the nation, the petroleum technology course at Orange Coast College, now in its second year, has not been organized to compete with petroleum engineering programs in scientific and cultural scope. It is anticipated, however, that a two-year technological terminal course will produce graduates ready to take their place in the petroleum industry in sub-professional capacities and, in time, in supervisory jobs. These positions, perhaps in usual sequential normality, are the same ones filled by the four-year graduate two years later. This brings up the probable conclusion that the functional two-year approach might be preferable if the advantages of earlier earning power, adjustment to the job, acquaintance with personnel, and orientation in company methods and policies are to be considered. The eventuality that the engineering graduate would supersede the technical graduate after a period of time is not overlooked. Yet, it would be likely to happen only in certain instances and would normally require considerable time.

TABLE I-A

Petroleum Technology Curriculum First Year

First Semester	*Units*
Introduction to the Petroleum Industry	2
Applied Mathematics and Engineering Problems	2
Physical Geology	3
English Composition and Technical Report Writing	3
Introductory Psychology	3
Physical Education	½
Elective*	3
	16½

Second Semester	*Units*
Petroleum Production Practices	2
Applied Science and Engineering Fundamentals	2
Historical Geology	3
Hygiene	2
English Literature	3
Physical Education	½
Elective*	3
	15½

* Electives in Engineering Drawing and Plane Surveying, or in supervised work in the oil fields, are strongly recommended. A minimum of one summer of practical experience will be required for the Associate in Arts in Petroleum Technology degree.

TABLE I-B

Petroleum Technology Curriculum Second Year

Third Semester	*Units*
Drilling Methods	2
Mud Control	2
Petroleum Geology	3
American History	2
Industrial Organization and Labor Relations	2
Physical Education	½
Electives*	5
	16½

Fourth Semester	*Units*
Refinery Techniques	2
Petroleum Tests	2
Geology of California Oil Fields	3
American Political Institutions	2
Physical Education	½
Electives*	6
	15½

* Electives in Mathematics and Science, in business Education, or in some of the other technological areas are recommended. Counselling for these should be judiciously effected on the basis of individual student aptitudes and requirements. ★ ★ ★

PETROLEUM BRANCH PROGRAM

AIME, 1950 Annual Meeting

Statler Hotel, New York City

FEBRUARY 11-15, 1950

Saturday, February 11

Morning and afternoon

Council of Local Section Delegates Meeting.

Sunday, February 12

Morning and afternoon

Joint Meeting, Council of Local Section Delegates and AIME Board of Directors.

Monday, February 13

Morning

Registration.

Opening Luncheon — All-Institute. Principal speaker, General Dwight Eisenhower, President, Columbia University.

Afternoon

PETROLEUM TECHNICAL SESSION

L. E. ELKINS and GAIL MOULTON, Presiding

The Microlog, a New Electrical Logging Method for a Detailed Determination of Permeable Beds, by HENRI G. DOLL, Schlumberger Well Surveying Corp., Ridgefield, Conn.

American Oil Shale Developments, by J. B. MULL, U. S. Bureau of Mines, Rifle, Colo.

Relative Productivity of Perforated Casing, by ROBERT A. HOWARD and MARSH S. WATSON, JR., University of Oklahoma, Norman.

Tuesday, February 14

Morning

PETROLEUM ECONOMICS SESSION AND PETROLEUM TECHNOLOGY SEMINAR

Economics Session, PAUL SCHULTZ, Presiding

Proration and Its Application to the Conservation of Oil and Gas, by LT. GEN. ERNEST O. THOMPSON, Member, Railroad Commission of Texas, Austin.

The economics portion of this session will be completed by an address of significance by another noted analyst. Details will be later announced.

Petroleum Technology Seminar

JOHN SHERBORNE and PAUL ANDREWS, Presiding

The Recent Past and Foreseeable Future of Production Technology

From the Management Viewpoint, by R. W. FRENCH, JR., vice-president, Sohio Petroleum Co., Cleveland, Ohio.

From the Engineering Viewpoint, by CHARLES V. MILLIKAN, chief engineer, Amerada Petroleum Corp., Tulsa, Okla.

From the Research Viewpoint, by MORRIS MUSKAT, chief, Physics Division, Gulf Research and Development Co., Pittsburgh, Pa.

Following each of these brief prepared observations, the meeting will be opened for audience participation.

Noon

All-Institute Ladies' Luncheon and Style Show.

Afternoon

PRODUCTION REVIEW SESSION

D. V. CARTER, Presiding

This session consists of brief presentation of world-wide development and production highlights of 1949. Presentation will be by the following members of the Petroleum Branch Production Review Committee, or their proxy.

Foreign, by E. W. BERLIN, Standard Vacuum Oil Co., New York.

Northeastern U. S., by GERALD EDDY, Michigan Dept. of Conservation, Lansing, Michigan.

Southeastern U. S., by JOHN K. WRIGHT, JR., Mississippi State Oil and Gas Board, Jackson, Miss.

Rocky Mountains, by RAYMOND M. LARSEN, U. S. G. S., Casper, Wyoming.

Pacific Coast, by L. E. PORTER, Richfield Oil Corp., Los Angeles, Calif.

Southwestern U. S., by R. B. GILMORE, DeGolyer & MacNaughton, Dallas, Texas. (Partial presentors to be announced.)

Mid-Continent U. S.—Presentor to be announced.

Evening

Petroleum Branch Cocktail Party and Dinner, ladies invited. Dress, informal for men, ladies optional. Installation of 1950 Petroleum Branch officers. Principal address, *Whose Business is This?*, by TOM ORR, executive secretary, Kansas Independent Oil and Gas Association, Wichita, Kansas.

Wednesday, February 15

Morning and afternoon

Open meeting, Executive Committee, Petroleum Branch.

Evening

All-Institute Banquet. Dress, formal preferred.

Personals

HAROLD DECKER has been named president of Houston Oil Co. and Houston Pipe Line Co., succeeding the late George A. Hill, Jr. Formerly vice president of Pan American Production Co., Decker assumed his new duties on January 1.

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J. C. BARTRAM, now manager of Stanolind Oil and Gas Co.'s exploration department, has been named consulting geologist. He has been with Stanolind since 1932.

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J. E. SWEARINGEN has been named Central division manager of Stanolind Oil and Gas Co. He was formerly executive assistant to the vice president in charge of operations.

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E. C. SARGENT, formerly with the Puenticitas Oil Co., is now with the Holly Development Co. as production superintendent for the Mid-Continent division. Sargent's offices will be in Corpus Christi.

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HARRY H. NOWLAN is president of the newly incorporated firm of Harry Nowlan & Associates. Its purpose is to service oil loans by making bankers' appraisals.

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BYRON L. PUMLEY is working as an engineering trainee for the Samedan Oil Corp. in Ardmore, Oklahoma.

STRANG RESIGNS FROM PETROLEUM BRANCH TO JOIN API

WILLIAM H. STRANG, executive secretary of the Petroleum Branch, resigned at the turn of the year to affiliate with the Production Division of the American Petroleum Institute, located in Dallas. He will assume his new duties within a few weeks.

Strang established the Petroleum Branch office in Dallas in April, 1946, and has been the first executive secretary for this part of the Institute. The Branch has expanded in membership and in the scope of its activities since that date, and the office staff now consists of five persons.

Prior to coming to the Branch, Strang was with the old Oil Weekly, and with the Continental Oil Co. He attended the Colorado School of Mines, and Oklahoma University, graduating from there in 1938 in petroleum engineering. He served in the Ordnance Dept. of the Army during the war, with final service as a Lieutenant Colonel.

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H. H. KAVELER, assistant to the vice-president, Phillips Petroleum Co., Bartlesville, Oklahoma, has been named chairman of the North Burbank Unit which has been organized to water-flood approximately 22,000 acres in the Burbank pool, Oklahoma.

HARVEY T. KENNEDY has joined the staff of the petroleum engineering depart of the Agricultural and Mechanical College of Texas as distinguished professor of petroleum engineering. Kennedy received his bachelor's degree in chemistry from Cornell University, and his Ph.D. in physical chemistry from Johns Hopkins University.

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H. C. PETERSEN has been made manager of the Freeport Sulphur Co.'s new oil and gas division. The division will have headquarters in New Orleans, with a branch office in Houston.

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DEAN H. ALLIS graduated in petroleum engineering from the University of Oklahoma last June and is now a trainee in the acidizing department of the Western Co., Odessa, Texas.

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J. VAN PAASSCHEN, after completing a contract with the Arabian American Oil Co. at Dhahran, Saudi Arabia, rejoined The Texas Co. in New York as reservoir engineer for the company's foreign producing department.

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T. J. VOGENTHALER, formerly with the Schlumberger Well Surveying Corp. as a junior engineer, is enrolled for a two-year graduate course at Harvard School of Business Administration.

The engineering committee for the Naval Petroleum Reserve No. 1, usually referred to as the Elk Hills field, met in Dallas from November 29 to December 4 in the offices of DeGolyer & MacNaughton for engineering and operating discussions. Those attending are pictured here from L to R: Lt. Comdr. Louis Kulot, inspector of Naval petroleum reserves; E. E. Adams, chief production engineer of the reserve; H. P. Stolz, consultant, Los Angeles; Max C. Eastman, member operating committee for the reserve; W. A. Eardley, Standard Oil of Calif; V. O. Wankowski, also a member of the operating committee; A. F. Turman, Standard of Calif.; L. W. MacNaughton, DeGolyer & MacNaughton, Dallas; J. E. Lindsay, Standard Oil of Calif.; and G. E. Woodward, DeGolyer & MacNaughton, Dallas.

Obituaries

SOLOMON R. GUGGENHEIM
Member 1923

A mining magnate and last of the famous Guggenheim brothers, died Nov. 3 at his home on Long Island at age of 88. Fourth of seven sons of a Philadelphia importer, Solomon was born when interest in the mineral resources of the West was on the rise. He gained mining know-how by investigation of prospective mining property purchases for his father. Solomon's first appraisal was a one-year stay at Leadville, watching operations of the A.Y. and the Minnie, as well as the Philadelphia smelter there. In 1889 he went to Mexico to take charge of the construction of the first lead-silver smelter; in 1891 he negotiated the purchase of a copper mine to add to the firm's holdings. Guggenheim Brothers' earnings from these, upon merging with AS&R in 1901, including a smelter in Pueblo and a refinery in Perth Amboy, totaled $4,500,000. AS&R acquired control of mining operations all over the world. Holdings of the Guggenheim Brothers were carried in individual Guggenheim names, with Solomon delving into Chilean nitrates while acquiring large Kennecott Copper holdings. In January 1940 he held 162,000 shares in Kennecott and this part of the family interests even through depression years had brought in a return up to $565,922 in one year.

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THOMAS ARNOLD DICKSON
Member 1941

President of the Colorado Iron Works Co., died in Denver on Oct. 19, 1949, at the age of 63. Ted Dickson was born in Leadville and his career, a brilliant one, was in the familiar American tradition of coming up the hard way without benefit of formal technical training. Unable to complete his education, he started as a smelter chemist's assistant, and at the age when many young men are starting their professional career, he was in charge of smelters in Mexico and Arizona. Later he branched into cyanide work on the Comstock Lode. Between employment on operating assignments he worked for Colorado Iron Works as a salesman of metallurgical equipment, laying the ground work of what was later to be his life work. In 1917 he returned to Colorado Iron Works as general manager and eventually acquired ownership of the company.

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CHARLES WILLIAM FARIS
Member 1949

A partner in Faris & Warren, consulting petroleum engineers, died in August 1949. Mr. Faris was born at Washington, D. C., in 1910, and studied petroleum engineering at Penn State. He worked for the O. R. Seagrams interests for a while and in 1936 joined Shell Oil as a junior exploitation engineer, becoming chief exploitation engineer in 1946. He and his partner opened their consulting office in Midland, Texas, in 1948.

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THOMAS KNIGHT KNOX
Member 1946

A former vice-president of the Republic Natural Gas Co., died March 7, 1949, ending an active and useful career as a geologist and petroleum engineer. Mr. Knox, who was born in Anniston, Ala., in 1896, had wide experience in the oil industry including two years as a drilling contractor and oil producer in Louisiana and Texas, four with Gas-Products Co., and nine as valuation and appraisal engineer with P. M. Biddison and Texla Royalty Co., Dallas. He became chief geologist of Republic Natural Gas when it was organized in 1935.

JOHN E. ECKEL is president of the newly-organized Petroleum Mechanical Development Company in Houston. Formerly vice-president in charge of engineering with the Oil Center Tool Company, Eckel is a petroleum engineering graduate of University of Oklahoma. He has been active in the petroleum industry for 20 years and is a member of AIME, API, Texas Society of Professional Engineers, Nomads, and the Texas Academy of Science. Secretary-treasurer of the new firm is Marvin R. Jones, a graduate of University of Oklahoma and formerly chief engineer for the Oil Center Tool Company.

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JOSEPH E. POGUE has been elected a director of the Gulf Oil Corp. He will serve in a consulting capacity.

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MAURICE LEWIS, JR., has been made a field exploitation engineer in Shell Oil Co.'s Wichita Falls division office.

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MAX I. BROWN is a logging engineer with the Hycalog Co. in Shreveport, La.

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JOHN E. COPPINGER is now employed by the Halliburton Oil Well Cementing Co. in Snyder, Texas, as a petroleum engineer trainee in the cement department.

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A. L. CROCKFORD, on concluding his course at the Camborne School of Mines, obtained employment with the Anglo-Saxon Petroleum Co.

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GEORGE DE MOHRENSCHILDT, consulting petroleum engineer and geologist in Denver, has been working recently in Utah, Wyoming and Montana.

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H. K. HOLLAND, JR., with the Magnolia Petroleum Co., has been transferred from Wichita Falls to Houston, Texas. ★ ★ ★

New officers of the Dallas Petroleum Engineers Club for 1950 are, left to right, H. B. Renfro, secretary-treasurer; A. E. Carraway, third vice-president; G. R. Brainard, second vice-president; Henry J. Gruy, president; Edward C. Cram, first vice-president; and T. S. Bacon, retiring president.

North Texas Section Activities

By Kenneth F. Anderson

A near-record crowd of 125 members and visitors attended the December meeting at the Blackstone Hotel in Fort Worth to hear John C. Calhoun, Jr., chairman of the School of Petroleum Engineering, at the University of Oklahoma, and member of the AIME, discuss the practical aspects of capillary forces in oil recovery. Chairman Don Harlan called the meeting together and Paul Riley introduced Calhoun, who gave an excellent discussion which was followed by a lively question-and-answer session. A summary of Calhoun's talk follows:

It is generally recognized that several major forces are to be considered in oil recovery, one of which is capillarity. Basic to the entire problem is the nature of capillary forces and the variables involved in computing their order of magnitude. The nature of the reservoir fluids and rock properties are fixed and means of changing these given conditions are quite limited. The effects these conditions have upon ultimate recovery, however, may be varied to some extent by the producing methods.

Calhoun stated that most of the research laboratories throughout the oil industry are devoting considerable attention to experiments which will lead them to a better knowledge of capillary forces and how to combat their detrimental effects. At this time, the basic principles are fairly well understood, but little is known about practical ways of dealing with those phenomena. Experiments (using small flood pots) have been made whereby an extraneous substance is introduced at the water-oil contact to lessen the quantity of oil left behind in a water-drive operation by reducing the surface tension of the oil. These experiments have resulted in a very high recovery of oil by water-flooding, but they are not practical because no suitable additive has been found that will not filter out as it moves through the porous media.

It was the speaker's opinion that under normal conditions, the rate which fluids move in a reservoir under mechanical forces is so great compared to capillary movement that capillary forces will not play a noticeable part in the displacement of oil under dynamic conditions. Capillary forces can be an important factor, however, in reservoirs that are undergoing gas-cap expansion or gravity drainage. Because of the difficulties in measuring capillary forces under dynamic conditions, most of the data available concerning capillary phenomena are from analysis based upon the static state.

Currently, Calhoun thinks the petroleum engineer's greatest use for capillary data lies in the estimation of connate water content, and for this the theory that water first occupied that portion of the reservoir now occupied by petroleum has to be assumed, which is by no means an established fact. ★

B. M. Kingston, left, and Paul Morrison, both of the Chemical Process Co., attended the meeting from Breckenridge.

Texas Sections Hold Joint Meeting at A & M

Observing a custom that is now in its fourth year, the joint meeting of the Texas Sections of AIME was held at Texas A & M College on December 8 and 9. Sponsored by the East Texas, Gulf Coast, North Texas, Permian Basin and Southwest Texas Sections, along with the University of Texas and A & M College student societies, the meeting has been held every other year since 1946 at one of the two institutions to acquaint the students with the AIME, and to promote inter-section acquaintance. Attendance this year was 247 industry representatives and students.

R. L. Whiting, associate professor of petroleum engineering at Texas A & M, served as program chairman, and was the guiding spirit behind an excellent program on a general theme of "Well Completion". Four half-day technical sessions were held during the two days, along with a banquet on December 8.

The traditional student paper contest was held with students from the University, A & M, and Texas Tech competing for prizes. Riley V. Carlton of Texas Tech won the $50.00 prize presented by the Gulf Coast Section, with his paper entitled *A Discussion of Some Important Factors Contributing to Corrosion Fatigue of Drill Pipe*. Roy C. Gould of A & M presented *The Advantages and Disadvantages of Dual Completions of Wells*, and William F. Nicodemus of the University of Texas presented *An Economic Analysis of the Water-Flooding of Oil Sands in North Texas*. All three students were presented a set of AIME *Transactions* by the Petroleum Branch.

J. E. Warren, president of Carl B. King Drilling Co., of Midland, delivered the principal address at the Thursday evening banquet, at which C. F. Underriner, president of the Petroleum Engineering Club of A & M presided, and W. S. Morris of East Texas Salt Water Disposal Co. in Kilgore served as toastmaster. In speaking on the subject of "Formula for Opportunity", Warren gave a brief resumé of the progress made in petroleum engineering during the past 25 years, and outlined some of the opportunities that exist now. He stated that the developments in reservoir control and secondary recovery alone illustrate the progress made in less than one generation and added that the opportunities open to the petroleum engineer are greater now than 25 years ago, provided our freedoms are maintained. "The maintenance of these freedoms demands the active participation of the nation's free-thinking people," he said, in recommending that colleges should put the recognition of freedom in their curriculum. He added, "The established trend of placing technical men in supervisory positions will continue, but we must preserve the essential ingredients of the opportunity formula."

Gravel-Pack Completions Discussed

Keen interest was evidenced in all of the technical papers presented, and free discussions were held on each after its presentation. Of unusual interest, because of the paper itself, and because of the nature of the material it contained, was a paper presented by Thomas S. West of Al Buchanan and Blanco Oil Co., entitled *A Gravel-Pack Completion for Exclusion of Gas and Water*. A summary of the paper follows:

The gravel-pack procedure described is primarily a selective completion method. Although complete sand screening is achieved, the exclusion of gas and water is the primary objective. The application of the procedure is therefore not limited to unconsolidated sands, but is equally applicable to hard sand and limestone reservoirs.

The optimum permeability of a gravel-pack which has been subjected to sand invasion occurs when the gravel has a diameter about six times that of the sand grains at the 10 per cent point

(Pictures at Right)

1 — A group of the speakers and presiding officers for the technical sessions, back row L to R: A. G. Gueymard, City National Bank, Houston; B. R. Weaver, Tide Water; R. E. Bush, Lane Wells; Bruce Barkis, B. & W.; A. B. Stevens, P. E. Dept., Texas A & M; and Robert Todd, Core Laboratories. Front Row: George Howard, Stanolind; G. H. Fancher, P. E. Dept., University of Texas; and Edward F. Kelly, Dowell.

2 — Other speakers and presiding officers are, L to R: E. H. Lancaster, Magnet Cove Barium Co.; H. T. Kennedy, P. E. Dept., Texas A & M; Thomas S. West, A. Buchanan and Blanco Oil Co.; Harold Vance, P. E. Dept., Texas A & M; and Warren Jackson, Lane Wells.

3 — A portion of those attending one technical session.

4 — Howard W. Barlow, dean of the School of Engineering of Texas A & M, extending his welcome to the meeting.

5 — J. E. Warren, president of Carl B. King Drilling Co., speaking on the "Formula for Opportunity" at the banquet on Thursday evening.

6 — W. S. Morris, East Texas Salt Water Disposal Co., serving as toastmaster for the banquet.

7 — The three students who presented papers in the contest, shown discussing one of the papers. L to R: William F. Nicodemus, University of Texas; Riley V. Carlton, Texas Tech; and Roy C. Gould, Texas A & M.

8 and 9 — C. F. Underriner, Jr., president of the P. E. Club of A & M, presiding at the banquet, and the emblem of the club.

10 — A group of A & M students attending the meeting. L to R: Walt Zimmerman, Jerome C. Kearby, Tom Calhoun, Fred Hambright and Alva G. Walsh.

11 — E. H. Lancaster, Magnet Cove Barium, and R. L. Whiting, P. E. Dept., Texas A & M, were co-authors of "Drilling Mud and Its Relation to Well Completions", presented at the meeting by Lancaster.

12 — Harry H. Power, P. E. Dept. at University of Texas, presiding at one of the technical sessions.

13 — A group of A & M students taking the opportunity to relax during the meeting are L to R: Joe H. Kemp, Maxie W. Freeman, John M. Casey, J. H. Berry, Jr., and W. J. Alexander.

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on the sieve analysis curve. Tests conducted by the author's company indicate that this is also the largest gravel size for which no sand production occurs. The point of no sand production would obviously also be the point of no sand invasion into the gravel pack. For gravel-sand size ratio larger than six, sand invasion occurs and reduction of gravel-pack permeability results. For gravel-sand size ratio less than six, little or no sand invasion into the gravel occurs, permeability decreasing primarily because the smaller gravel has a lower permeability.

The method described by the paper consists of placing layers of gravel and sand and gravel mixtures, having the same order of permeability as the producing sand, through the producing formation. Screening is achieved through the composition and placement of these layers.

In placing the gravel a 2-in. pipe size liner is employed. The lower end is closed. Milled or hacksaw-cut slots 1/32 in. in width are usually employed. The upper end of the liner is closed with a conical cap which is held in place by a shear pin. This cap is formed to fit a wire line core-barrel type overshot, this overshot being used for lowering the liner to the bottom and for retrieving the cap. The liner top is also attached to a mandrel of slightly smaller diameter than the inside diameter of the liner. This mandrel extends to near the bottom of the liner for strengthening the liner against bending and for facilitating the recovery of the cap should it be accidentally pulled out of the liner.

Gravel is dumped around the liner in relatively small batches by means of a bailer which has the bottom end closed by a frangible disc, usually a steel rimmed cement disc. Plate glass has also been employed for this purpose. When the disc strikes the liner top it is broken, allowing the gravel to settle to bottom, and noting the pick-up or jerk on the wire line when the bailer leaves bottom. Quite accurate measurement of fill-up may be obtained in this way — usually to within about two inches. When sufficient gravel has been deposited to fill to at least four or five ft above the liner slots, a mixture of quick-set cement and sand is dumped employing the same bailer. The quantity of cement employed is such that the cap and top four or five ft of the liner remains exposed. When the cement has set, this cap is retrieved by catching along with a wire line overshot and bringing it and attached mandrel to the surface.

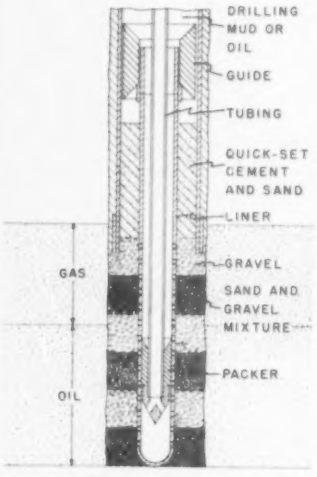

Fig. 1 — The gravel pack used for exclusion of gas and water.

Fig. 1 illustrates the gravel pack used for the exclusion of gas and water. Alternate layers of gravel and a mixture of sand and gravel each usually about 1-ft thick are dumped around the liner opposite the sand section and usually to at least 5-ft above the highest liner slot. A quick-set cement and sand mixture is then dumped on top of the gravel and in sufficient quantity to extend to within about 5-ft of the top of the liner. The gravel layers have a grain size about six times that of the sand grain at the 10 per cent point on the sieve analysis curve. This grain size is usually about 1/16 in., and might be described as being a coarse gravel. The mixed layers are composed of gravel of this size mixed with enough sand to fill its pore spaces. To prevent the gravel and sand from separating when dumped, it is necessary to use a binder which will prevent the separation and which will also flow out with about 50-lb pressure differential leaving a permeable layer in which the sand and

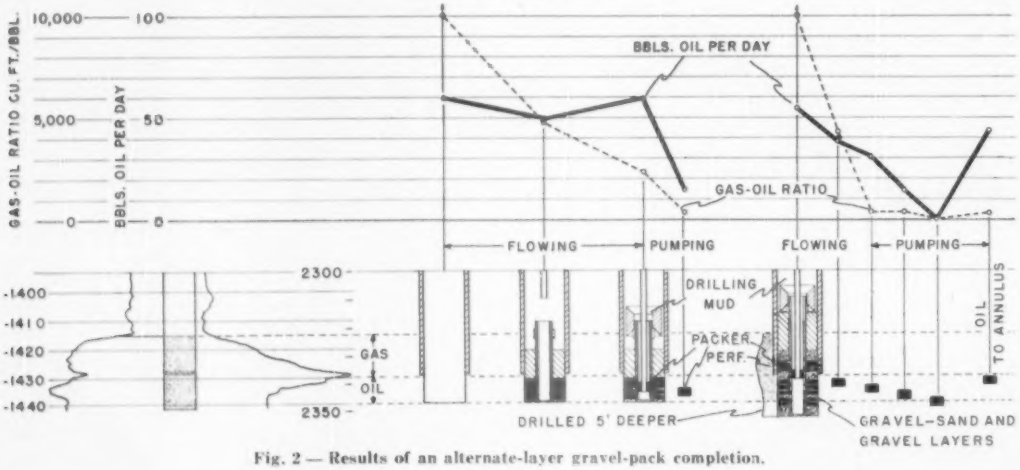

Fig. 2 — Results of an alternate-layer gravel-pack completion.

gravel are thoroughly mixed. The gravel content of these layers prevents the mixture from flowing through liner slots of the size suitable for the clean gravel layers. By using sand of about the grain size of the oil sand, or slightly larger, a mixture results through which drilling mud will not flow because of the formation of an impermeable filter cake. Thus by running a cup type packer on the tubing to a desired level in the slotted portion of the liner and filling the annular space between the casing and tubing with drilling mud having a hydrostatic head exceeding static bottom-hole pressure, a positive shut-off of the sand section above the packer results while fluid production is secured from below this level. This shut-off occurs because the mud invades the clean gravel layers forming a filter cake on the face of the sand and at the interface of the clean and mixed layers. Since the hydrostatic head of the mud exceeds the formation pressure, gas for example, cannot flow through or into the mud-invaded sections while the mixed layers prevent the mud from flowing downward through the gravel pack past the packer and into the tubing. A completion is thus provided which not only results in a positive shut-off but which also provides for changing the producing level by the simple procedure of raising or lowering the tubing. The optimum producing level may be found after completion, making accurate information unnecessary as to the location of the gas-oil contact or a preliminary guess as to what extent coning may occur or dependence on the gas-oil contact remaining at the same level. Precise depth measurements are also not necessary.

If water production develops, this may also be excluded by use of a double packer assembly having a mud by-pass from above the upper to below the lower packer. The clean gravel layers both above and below the producing level are in this case invaded with mud under pressure exceeding the bottom hole pressure while oil production is secured from the space between the two packers. Both gas and water may be simultaneously excluded in this way. Any desired section of the sand may be selected for production.

This method provides for obtaining a shut-off in the hole space only, and does not provide for prevention of downward coning of gas or upward coning of water through the sand section in the immediate vicinity of the hole. However, the alternate layer type completion also makes possible the correction of this condition. If, for example, high gas-oil ratio develops because of vertical coning, the mud in the annular space between casing and tubing may be replaced with oil. By first raising the packer to back-flow, the mud invaded layer filtered oil may be injected into the gas sand above the level of the packer. By continuous injection of oil into this section, oil saturation is maintained in the zone in which gas coning previously occurred. This results in some oil flow along the coning path from above the packer into the tubing and, as the packer is raised, it is necessary to supply increasing quantities of oil to the space above the packer, resulting in a greater amount of oil circulation. However, so long as any oil column exists in the sand, it should be possible to produce with low gas-oil ratio.

Fig. 2 shows the results of an alternate layer type completion to a well in the Quien Sabe field in Webb County, Texas. Production is from the Lopez sand of the Mirando series at about 1430 ft subsea. About 15 ft of gas saturation is present in the upper portion of the sand section with about 6- to 9-ft of oil saturation in the lower part. Casing was set approximately at the gas-oil contact, and the lower portion of the sand section was packed with alternate layers to within about 3-ft of the bottom of the casing. A non-permeable mixture of gravel, sand, silt, aquagel and grease was placed in this space. The liner was then cemented in the usual manner, and a 24-hour test yielded 48 bbls of oil flowing through ¼ in. choke with gas-oil ratio of 4700 cu ft per bbl. A special packer was then installed, and the results of tests with the packer set at various levels are shown in the figure.

Since it was believed that the entire sand section had not been penetrated, the gravel pack was removed and the well drilled 5-ft deeper with a spudder. The bottom 5-ft of the casing was then perforated to provide a greater zone for oil injection into the gas section. This section was again gravel-packed with alternate layers 1-ft thick, and the liner cemented. Tests were again run with the packer at various levels with the following results: 12 ft below casing, no production; 9 ft below, 14 B/D pumping, GOR 250; 7 ft below, 31 B/D pumping, GOR 250; 4 ft below, 38 B/D flowing, GOR 4,200; above perforated liner, large gas volume with spray of oil. After washing, the packer was set permanently at 4 ft below casing, and with mud in the annulus, the well was

Continued on Page 35

Fig. 3 — Surface equipment used on oil circulation type completion.

Oklahoma City Section Activities

By Harold Sells

December Meeting

The December meeting, held at the Biltmore Hotel, featured a lecture by William D. Owsley, Halliburton Oil Well Cementing Co., and the election of Local Section officers for the coming years. Officers elected are as follows:

Chairman, Henry Waszkowski, Magnolia; 1st Vice Chairman, Martin Hegglund, Stanolind; 2nd Vice Chairman, Kenneth Fink, Shell; Secretary-Treasurer, H. R. Sells, Sohio.

Directors: Chas. E. Clason, Halliburton; C. L. Kirkman, Lane-Wells; Lincoln Elkins, Sohio (chairman for 1949).

Owsley ably presented the latest improvements in the techniques, materials and equipment used in cementing operations. This talk is a typical example of the direct information which the AIME Local Section desires to present to its audience. In the last analysis, keeping members abreast of the latest improvements in developmental and production engineering techniques and operations is one of the primary reasons for the existence of the Petroleum Branch. Correspondingly, the greatest benefit which a member receives by regularly attending monthly meetings is receiving information concerning new procedures, improvements made in old techniques and the informal reports of actual field results from members who have applied these advanced techniques.

January Meeting

The program for the January monthly meeting will be a paper by M. P. Tixier of the Schlumberger Well Logging Corporation in which he will discuss the estimation of permeability of the formations using the resistivity curves from the electric log. This meeting will be held at the Biltmore Hotel at 7:30 p.m. on January 19, 1950.

Henry Waszkowski, Oklahoma Div. engineer for Magnolia, is 1950 chairman of the Section. He was vice chairman during the past year.

Banquet Honoring Director of U. S. Bureau of Mines

A special feature of the Section activities during December was a banquet honoring James Boyd, director of the U. S. Bureau of Mines, and a number of other officials with the Bureau, December 8, at the Biltmore Hotel. The Colorado School of Mines Oklahoma City Alumni held a reception for Boyd and associates preceding the banquet. Guests from the Bureau of Mines, in addition to Boyd, were H. C. Fowler, supervisor of the Bartlesville Station; Harold Smith, superintendent of Chemical and Refining Section, Bartlesville Station; Clifford W. Sibel, Bureau Southwestern regional director; Harold W. Thorne, Bureau of Mines, Laramie, Wyoming; and Ken Eilerts, Bureau of Mines, Bartlesville Station.

Boyd was guest speaker for the evening. His remarks were centered around facts which emphasized the high rate of consumption of basic resources in the United States. A striking graph illustrated the United States, with 7 per cent of the population of the world, produced and consumed a major portion of the minerals of the world. During 1948, the United States mineral production reached a value of $12,000,000,000.

Another striking table showed that the United States has gradually changed from a net exporting nation to a net importing nation on three of the basic

A group discussing cementing practices with William D. Owsley, left, at the December meeting were L to R: Jack Tarner, Phillips; Otis Danielson, Kerr-McGee; and Ralph W. Workentin, Lane-Wells.

An informal group at the December meeting were L to R: Ed. M. Saye, III, Lane-Wells; Gerald S. Young, Magnolia; Roy F. Beery, Danciger; and Charles Clason, Halliburton.

metals — copper, lead and zinc. Touching upon the reserves of basic metals in the United States, Dr. Boyd mentioned the fact that methods of reserve estimations and comparisons are admittedly incorrect but that no one has devised a procedure which would saisfactorily replace the present method. This method is the same as that which has been used in the petroleum industry form any years and consists of comparing the present known reserves upon the basis of the present yearly consumption. Using this basis, it is apparent that the United States is on the road to depletion in many of our basic metals. For example, exhaustion of our lead resources would occur in 1959 — copper in 1968 — and zinc in 1969.

Chromite resources are zero since we have always been an importer of this metal. However, on the other hand we have tremendous resources of coal, iron ore and phosphate; as an example, it is estimated that we have sufficient coal to last this country for 3,000 years. Boyd mentioned the fact that more efficient methods must be used in the production of all basic minerals. We leave in the ground approximately 50 per cent of petroleum, in the neighborhood of 30 per cent of natural gas, and for less obvious reasons, approximately 30 per cent of the coal mined is left underground. A smaller percentage remains underground for other metals but the remainder unclaimed is still appreciable. Comparing our fuel reserves upon the basis of energy content, Boyd stated that 95.5 per cent of our fuel reserves were in coal, .4 per cent in petroleum, .4 per cent in natural gas and 3.6 per cent in oil shale. However, we are consuming the above resources at the rate of 54 per cent coal, 32 per cent oil and 14 per cent natural gas. It is apparent that at some future date the United States will have to reorient its greatest consumption to correspond with the actual fuel reserves of the country.

Although considerable discussion has circulated relative to the exhaustion of our iron ore resources, there is no question concerning the exhaustion within the immediate future. It is true that only a small quantity of high grade ore is at present available and that this will soon be exhausted. However, tremendous quantities of "so called" low grade ore are available for consumption. This is approximately 35 per cent ore; however, it is well to note that England has used 28 per cent ore for many years. Millions of dollars have been spent by industry to develop more efficient methods for processing this low grade ore. Entering this picture is also the possibility of the development of other metals which may be a substitute for iron and other metals which are commonly used today. For example—titanium—which is lighter than steel, although heavier than aluminum and which is corrosion resistant and possesses structural strength equal or superior to that of carbon steel. With regard to a substitute for petroleum the government has inaugurated an extensive research program for pilot plants for the production of synthetic fuel.

Boyd emphasized the fact that the government is not going to set up a synthetic fuel industry to compete with natural gas and petroleum. The impetus which was given to development of synthetic fuels was provided by World War II. To those who were given the task of estimating the amount of petroleum which would be available for the war effort, it appeared that the United States was able to provide all of the petroleum necessary. However, it appears that sometime in the not too distant future the United States will become a permanent importer of petroleum. The calculated amount which could be found in the future by advanced prospecting methods eventually levels off and equals the estimated future rate of consumption, and then becomes less than the estimated annual United States rate of consumption. It appears that the amount of petroleum discovery will decline and that eventually the amount of petroleum produced will not be sufficient. Estimates of the date at which this turning point will be reached vary considerably, and at this time, appears to be somewhere between 1955 and 1970.

The question is one of defense. We must develop synthetic fuels and shale oil faster than the normal economic development of section industry because of this defense factor. To wait for the normal economic development could be fatal to the country. At the present time tremendous strides have been made in the mining and refining of oil shale. However, it is not in economic competition with crude petroleum. It is to be emphasized that it is not the intention of the administration to go beyond the experimental stage in the development of the oil shale industry.

Following Boyd's talk the meeting was opened to questions and general discussion. An interesting question concerned the re-use of metals. Dr. Boyd stated that, for example, copper is used again and again; zinc is re-used considerably but is more destructible than copper; that lead is re-used extensively, with the exception of lead used in tetraethyl and other compounds. The used metal market in aluminum is also becoming more extensive. During the last war Germany developed extensive methods for the conservation and re-use of her stock-piled metals. Copper, for example, was used many more times than it was in this country.

H. C. Fowler was introduced by Boyd and presented a few comments concerning the Bureau's Bartlesville Station. This station was established in 1918 and it is financed 10 per cent by the State and 90 per cent by the United States. Overall budget is in the neighborhood of $600,000 per year. Some projects in progress at the present time are those of phase relationship, secondary recovery research, and the examination of sulphur in petroleum. A research program instituted recently at the Station is a study of the use of radio-isotopes as a tracer in water-flood operations.

Harold Smith commented upon research being done by the Chemical and Refining Section at the Bartlesville Station. One of the projects consists of a study of the sulphur compounds in crude petroleum and the tabulation of the physical properties of these compounds for the purpose of future analysis and separation in various crudes. A study is being conducted of the composition of diesel fuels. This study is in approximately the same position as the similar study of gasoline was 25 years ago. Analyses are being conducted using infra-red and ultra-violet methods and also by the actual separation of the hydrocarbons. Properties of these compounds are secured and correlated with the burning qualities of diesel oil.

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Gulf Coast Section Activities

By J. E. Kastrop

William C. Goins, Jr., Gulf Oil Corp., Houston, addresses the December 13, 1949, meeting on the subject, "A Study of Limed Mud Systems".

E. L. Petre, Gulf Oil Corp., Houston, was unanimously elected December 13 to succeed Owen Thornton, The Texas Co., Houston, as the new chairman of the Gulf Coast Section. G. D. Robertson, Shell Oil Co., was elected vice chairman. George Fancher was elected as the vice chairman from the University of Texas, and A. B. Stevens as vice chairman from Texas A & M College. Elected to a second term as secretary-treasurer was A. G. Gueymard, The City National Bank, Houston. J. E. Kastrop, World Oil, Houston, was elected as Section Delegate for a two-year term. The following were elected to the board of directors to serve for varying terms: Owen Thornton; Fred Nelson, Texas Gulf Sulphur Co.; L. V. Uhrig, Humble Oil & Ref. Co.; E. R. Rassinier, Phillips Petroleum Co.; and E. B. Miller, Tide Water Associated Oil Co.

An overflowing attendance of 101 members and guests were present at the Section's final meeting of the year held at the Houston YMCA. Election of officers and committee chairman reports highlighted the business session. Thornton, presiding over the business session, called upon outgoing committee chairmen for their annual reports. Petre, as 1949 chairman of the program committee, praised the cooperation of his committee which included Tom Borland, Stanolind Oil & Gas Co., R. W. Holman, The Texas Co., E. H. Lancaster, Magnet Cove Barium Co. and J. R. Welsh, Humble Oil & Ref. Co.

New officers of the Gulf Coast Section, include, from left to right, in foreground, E. L. Petre, chairman; A. B. Stevens, vice-chairman from A & M College. In the back row, left to right, are: E. B. Miller, director; E. R. Rassinier, director; A. G. Gueymard, secretary-treasurer; and J. E. Kastrop, Section delegate. Not shown are: G. D. Robertson, vice-chairman; George Fancher, vice-chairman for The University of Texas; Fred Nelson, director; Owen Thornton, director; and L. V. Uhrig, director.

E. A. Rassinier, chairman of the progressive membership committee, reported that the Gulf Coast Section was second in the number of new members gained during the year, thanks to his committee, composed of the following: Herman Otto, Tennessee Gas Transmission Co.; Harry Arendt, Humble Oil & Ref. Co.; C. W. Trice, Stanolind Oil & Gas Co.; and R. P. Ridley, The Texas Co.

Chairman of the important house committee, K. B. Ford of J. R. Butler Co., expressed his appreciation for the excellent arrangements for each meeting to members of his committee which consisted of: Leo McConnell, Lane-Wells Co.; Robert L. Hoss, Humble Oil & Ref. Co.; D. C. Stallworth, Abercrombie Co.; and Marion Olive, J. R. Butler Co. Leon W. Huebel, Baroid Sales Division, served as chairman of the activities committee, and J. E. Kastrop was head of the publicity committee. George R. Gray, Baroid Sales Division, and L. V. Uhrig represented the Gulf Coast Section of AIME on the Houston Engineers Council.

Upon relinquishing the chairmanship of the Section, Owen Thornton was given a vote of appreciation for a job well done during 1949. In accepting the new post as the 1950 chairman, Petre expressed his hope to continue the good work.

Limed Mud Systems

Principal speaker of the evening was William C. Goins, Jr., Gulf Oil Corp., Houston, who discussed "A Study of Limed Mud Systems". Limed muds, popular in the Gulf Coast, have several advantages over fresh water mud, namely: immunity to cement contamination, a greater toleration for dispersed shale before giving high viscosity, less gelation from salt water intrusion, and the ability to successfully drill heaving shale zones that would be difficult to drill with normal fresh water muds. The speaker discussed some of the physical and chemical characteristics of limed muds to explain some of the heretofore unknown functions of the

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Pacific Petroleum Chapter Activities

By Frank S. Parker

The Petroleum Technology Forum met November 28 to hear Carl Tutschulte, engineer of the Tide Water Associated Oil Co., Los Nietos, California, discuss engineering features of the Porter Pool of the Aliso Canyon oil field. Tutschulte is a graduate of California Intsitute of Technology and had worked at various engineering operations for Shell Oil Co. for a number of years before joining Tide Water Associated. The paper gave the results of a long and intensive engineering study of production problems which can be reviewed only briefly in these few paragraphs.

The Aliso Canyon oil field is located in the Santa Susana mountains approximately six miles west of the city of San Fernando. The field is situated at a considerable distance from existing highways in extremely rugged terrain and as a result a large amount of excavation has been required to construct the necessary roads and rig sites.

The discovery well of the field and of the Porter Pool was completed on October 25, 1938, flowing at a rate of 1200 B/D through a 40/64 bean at a depth of 5365 ft. The development of the pool continued at a relatively slow pace, two wells being completed in 1939; seven wells in 1940; five wells in 1941; two wells in 1942; one well in 1943. A hiatus in drilling activity of over five years was followed by two wells in 1948 and one well in 1949. The Porter reservoir is a southerly dipping homocline which is bounded on the south and southeast by an active water front, on the west by a stratigraphic barrier formed by the progressive lateral transition from sand to siltstone, and on the north and northeast by the Santa Susana fault, which forms an impermeable barrier against which the oil in the Porter Zone has accumulated. The Porter Zone is encountered at a depth of from 4700 to 5400 ft below the surface and is comprised of sediments of shallow marine origin of the Pliocene age. The thickness of the zone ranges from 60 to 800 ft with the average being approximately 450 ft and the average thickness of producible sand being approximately 180 ft. The average porosity and permeability within the reservoir based on 347 samples from 7 wells is 24.8 per cent and 1200 md. respectively and the interstitial water is 26 per cent based on capillary pressure data.

The hydrocarbons originally contained in the Porter reservoir appear to have been undersaturated and the existence of a primary gas cap is very doubtful. The values of oil gravity, 23.5 API; solution gas oil ratio 240 CF/B; and the saturation pressure 1625 psi; measured in this pool are much lower than is normally found in California oil pools of comparable depth.

Carl Tutschulte of Tide Water spoke on the Aliso Canyon field Nov. 28.

The performance history indicates that the production performance of the pool has passed through at least three stages, i.e., (1) an initial period when the recovery mechanism was almost entirely dissolved gas expansion, (2) an intermediate period during which the oil producing energy was the result of both dissolved gas drive and water drive, and (3) a third period when the water drive has been the principal

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Ralph Trueblood, left, and Pohn Nichols preparing slides and program data for speaker at the meeting.

R. H. Smith, left, and C. H. Dodson waiting for the meeting to begin.

Junior Section Activities
Pacific Petroleum Chapter

By I. A. Marshall, Jr.

Fifty engineers attended the December 8 meeting at the Rio Hondo Country Club in Downey, California. The meeting was opened by Chairman C. T. McClure who announced that the price of the monthly meetings would be raised for non-members starting with the January meeting. He explained that this was being done in order to induce non-members who attend the meetings to join the AIME and also to increase the Section revenue so that it may become as financially independent as possible. He then announced that the executive committee had nominated Norman B. Clark for 1950 chairman. The nomination was seconded from the floor and as no other nominations were forthcoming, Norman B. Clark was unanimously elected chairman and took over his duties by introducing the speaker of the evening, J. J. Jakosky.

Jakosky, an independent geophysical consultant in the Los Angeles area, began his talk in geophysical methods by giving a brief outline of the history of the three most commonly employed geophysical methods. The magnetic method is by far the oldest, having been used in crude form as long ago as 2000 B.C. In its early form it consisted of a megnetized needle similar to a compass and was used in Sweden to locate iron deposits. The modern magnetic geophysical instrument, called a magnetometer, was first developed about 30 years ago and in its present form has an accuracy of about one part in 25,000. In recent years the magnetometer has been installed in airplanes and, although slightly different from the surface instrument, still employs the same principles. The flying magnetometer has an accuracy of approximately one part in 50,000. Although it is the least expensive of the magnetic methods, it is only used for general subsurface reconnaissance of large areas.

The gravity method of geophysical exploration was first employed about 1671 A.D. and consisted of a weight suspended from a sensitive spring. The modern instrument, known as a gravitometer, was first used in 1928 and in its present form has an accuracy of about one-ten millionth of the earth's gravitational force. The first oil field discovered by this method was the famous Spindletop field.

The third geophysical method is the seismic or "artificial earthquake" and was first employed in about 1860. It was being used around 1905 for locating sand domes in the Mid-Continent and Gulf areas. Like most geophysical and geological methods, the degree of effectiveness of seismology decreased as the more obvious and shallower structures were found. This method, however, is still used and it is estimated that approximately 90 per cent of the oil discoveries have been made by the seismic method using either the refraction or the reflection technique or a combination of both. Jakosky illustrated his talk with several slides showing diagramatically how various geophysical methods are used. He stated that geophysical exploration can only be expected to give about 21 per cent results when employed for the location of oil reservoirs. It should, however, be understood that several conditions must exist before a commercial oil reservoir can form. All of the geophysical methods indicate only one thing, and that is the existance of possible traps, whereas to have an oil reservoir it is also necessary that there be source beds, sufficient porous reservoir rock, an impervious over-burden or cap rock, and sufficient reservoir permeability.

As to the relative cost of the different geophysical methods, the magnetic method is by far the least expensive, amounting to about $500 to $750 per month, whereas the gravitational method will average about $3,000 to $5,000 per month and the seismic method considerably more depending on the depth to which the shot holes must be drilled, the amount of explosives that must be employed, and the type of terrain.

In using the magnetic method it is essential that the operator accurately determine his position with respect to longitude and latitude in order to correct the instrument for the earth's magnetic field. For instance, in the southern hemisphere the earth's magnetic lines of force dip in a southerly direction thus offsetting the magnetic survey in a northerly direction from the beds which are being recorded. In the northern hemisphere, of course, the opposite would be true. The degree of magnetism a bed or geological structure may exhibit is dependent on the amount of magnetic materials which it contains. The most common magnetic material is Magnetite. The basic principle of the

From left to right, some of the Section members and their guests are D. C. Nellis, Shell Oil Co.; E. D. Smith, Shell Oil Co.; John Woodman, Jr., St. Anthony Oil Co.; W. G. Paul, Jr., Kobe, Inc.; J. Hamb, R. Dwyer, R. L. Alder, and D. D. Loos.

magnetometer is, of course, the measurement of changes in the degree of magnetism of an area under observation. In the case of sedimentary beds having a rather high content of magnetic materials, and having been uplifted by a salt dome, the magnetometer would record a reduced magnetic influence at the top of the structure where the sedimentary beds were the thinnest. If, however, the intrusive body had a higher magnetic content than the overburden the magnetometer would record an increasing degree of magnetism as the crest of the structure were approached since the intruded body is closer to the surface at its crest. It is possible, however, to have the same indicated trends on the magnetometer when passing over a syncline or an anticline. The interpretation of whether the structure is favorable for the accumulation of oil must be supplemented with some geological information of the area under observation.

One of the most important fields discovered by the magnetic method was the Hobbs field in New Mexico where the discovery well was drilled at what appeared to be the crest of the structure as determined by a magnetic survey. Even though the well was a producer and proved the existence of an oil field, it was later determined to be an edge well and illustrates how a magnetic survey may be offset from the structure it is attempting to delineate.

The high altitude magnetometer now used for mapping large areas is supplemented for more detailed work by a magnetometer mounted in a helicopter. The helicopter can hover a few feet off of the ground making detailed readings regardless of the inaccessibility of the terrain. It is thus common practice to map an area with a high altitude instrument and then make a detailed survey of the more likely areas with the low altitude instrument.

The gravimetric method operates on the principle of measuring changes in the earth's gravitational force resulting from changes in the density of subsurface structures. Minerals are usually the most dense with igneous, sedimentary, and fill materials grading downward in density. Thus, if the gravitometer is operated over a syncline having igneous or mineralized beds the readings (recorded in milligals) will decrease since at the center of the syncline the more dense materials are farther from the instrument. The opposite would be true in the case of an anticline unless the intruded material had a low density, as in the case of a salt dome. As a general rule, the gravimetric method endeavors to locate gravity lows. The gravitometer is commonly transported in a truck having an opening in its bed so that the instrument tripod can be lowered to the ground and, while the bed of the truck acts as a windbreak, readings can be made from within the truck. Portable gravitometers carried on a man's back are also used although they are much slower and are not as accurate. For making gravimetric readings under water a buoy or diving bell is employed which houses the gravitometer and an operator and is lowered to the bottom where the readings are made. This method has been used by the Union Oil Company in its Gulf Coast exploration. In order to eliminate the necessity of having an operator in the bell, a remote control apparatus has been developed which can be lowered to the bottom and adjusted from the surface, the readings being automatically recorded.

The speaker at the Section meeting on December 8 was J. J. Jakosky, International Geophysics, Inc., Los Angeles, California.

Seismology, which is the most commonly used geophysical tool, operates on the principle of creating a shock wave either above or below the surface of the strata being studied and then recording the reflected and refracted waves at various points on the surface. If the shock wave were induced in a homogeneous material having a constant density there would be no reflections; however, the density of almost all lithologic sections varies considerably and the reflection is obtained at the point of change of density. There are basically three types of waves induced by the shock wave: (1) the surface wave or horizontal vibration emanating from the source of the shock; (2) the reflection wave which returns to the surface after encountering a change in density; and (3) the refraction wave which travels from the shock source to a point of density change, follows the contour of the material to another point, then is reflected to the surface again. The seismic method is particularly applicable to continuous beds such as are found in certain parts of Texas and Oklahoma. It is extremely difficult to interpret highly faulted or displaced beds since the shock waves tend to cross faulted areas unless there is some major interference. Seismology has been particularly effective in locating salt domes and for this application it is common practice to use a "fan" pattern of spacing the geophones. The average salt plug will have a wave transmission velocity of approximately 16,000 to 18,000 feet per second. In exploring an area in which there have been no wells drilled, the seismologist must assume an average wave velocity. However, if there is an existing well in the area, he can obtain accurate velocities by lowering a geophone or seismic recorder into the well and making velocity checks while inducing shock waves at the surface with explosives. The most common practice for inducing a shock wave is to drill a slim hole and detonate an explosive near the bottom of the hole. The purpose of this is to place the explosive below the "aerated" zones which are poor conductors of energy. In California it is common practice to drill shot holes to depths of 50 ft to 200 ft, 500 ft being the average in the Cuyama Valley.

A new method of inducing shock waves which has met with some success is the air method in which the explosives are detonated about six feet above the surface of the ground. The principle is to induce a shock which has a low unit stress and thus very little crushing action on the aerated beds. The effect might be compared to the

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East Texas Section Activities

By P. E. Des Jardins

Officers for 1950 were elected at the December 13 meeting in Kilgore. By a unanimous vote of those attending, the slate of officers recommended by the nominating committee were elected. They are as follows: Phil J. Lehnhard, East Texas Engineering Committee, Section chairman; W. W. Leonard, Continental Supply Co. in Shreveport, vice chairman, and P. G. Burnett, Stanolind Oil and Gas Co. in Kilgore, secretary-treasurer. Directors elected were: R. K. Thies, Schlumberger in Tyler; W. S. Morris, East Texas Salt Water Disposal Co. in Kilgore; B. F. Patterson, Jr., The Texas Co. in Shreveport, and P. E. Des Jardin, Shell Oil Co. in Kilgore.

Present directors with one-year term remaining are John Bell, Humble Oil & Ref. Co. in Tyler; R. M. Hess, Shell Oil Co. in Kilgore; and W. M. Jones, Stanolind Oil & Gas Co. in Longview.

The feature of the evening was an address on "A New Approach to Gun Perforating" presented by Bliss Adamson, supervisor of engineering and production for electrical well services, with Halliburton at Duncan, Oklahoma. After reviewing the history of gun perforating and the many applications which it has found in the petroleum industry, Adamson listed the factors which research has shown to have a bearing on the penetration results obtained from present equipment. These factors included:

Penetration results in a surface test of a new gun designed with five factors under consideration. These factors are explained in the accompanying text.

1. The gun size should be as large as possible for any given pipe size, for maximum penetration.

2. Variations in the angle of approach of the projectile to the pipe will be experienced due to the position of the gun with respect to the pipe.

3. Bullet breakage is affected by angle of approach of the projectile to the pipe.

4. Variations in burr characteristics were noted due to position of gun with respect to pipe.

5. Wear of gun barrels effects penetration.

A new gun has been designed with these factors in mind. It is arranged so that all gun barrels fire in the same direction. A drag spring located on the opposite side of the gun from the firing ports holds the gun in such a position that the muzzles of the barrels are always against the casing. With this design, the size of the gun is not a critical factor in penetration, since the gun muzzle will always be against the pipe, and increased penetration can be expected since the gun is positioned so that the approach of the projectile to the pipe will always be radial.

The projectile used in this gun is equipped with an expanding gas seal which minimized the effect of barrel wear, since all of the explosive force of the powder charge is trapped behind the projectile until it leaves the muzzle of the gun.

Adamson displayed several slides showing the results of surface tests made with this gun. These slides illustrated the reduced amount of burring of the casing and very good penetration obtained by use of this gun. ★ ★ ★

Part of the new officers and directors for 1950 are L to R: P. G. Burnett, secretary-treasurer; R. K. Thies, director; P. J. Lehnhard, chairman; P. E. Des Jardins, director; and W. S. Morris, director.

Bliss Adamson, supervisor of engineering and production for electrical well service at Halliburton, spoke on "A New Approach to Gun Perforating" at the December 13 meeting.

Illinois Basin Chapter

By Richard W. Love

Fred C. Newman, of the Old National Bank in Evansville, Indiana, spoke on oil loans at the December meeting. Starting as a mail boy with the bank in 1925, he rose to a vice presidency in 1948, and assumed charge of the oil department in 1949.

"Bank Financing in the Oil Industry" was the title of a paper presented by Fred C. Newman, vice president of the Old National Bank in Evansville, Indiana, at the December 8 meeting of the Chapter in Mt. Vernon, Illinois. A synopsis of the paper follows.

Since most of the transportation, refining and marketing of oil is done by the major companies, the financing for these operations is usually obtained in the large money markets of the country. Consequently, local financing is usually confined to the drilling for and production of oil. Loans are not made on exploratory drilling, as they are too speculative. They are made for the drilling of producing wells, and on producing properties, after the property has been appraised by a petroleum engineer. Banks have found from experience that the extension of credit to competent oil operators, to be liquidated out of oil income, when such properties have been carefully appraised, to be among the best type of earning assets of the bank.

For the purposes of financing, accurate appraisals by the petroleum engineer are of the utmost importance, since loans are based on the reserve of oil for the properties concerned. Banks maintain complete files on petroleum engineers who perform these services, and continual checks against actual performance are made on engineer's previous reports.

Granting of an oil loan follows a general procedure. Financing of the first well by a small operator usually comes from his associates. If it is a producer he may drill another well or so, but he reaches the point where he and his associates can no longer finance the operation, and he goes to a bank. The bank obtains complete information on the formation, and on the interest owned by the applicant for the loan. The interest owned is of prime importance, as the loan is usually declined if the interest does not provide operating control. The applicant is asked for a financial statement and references, all of which are checked.

The next step is to have the property submitted for collateral appraised by a petroleum engineer. The future reserves belonging to the applicant's interest are estimated, and a loan value attached based on the current price of oil. The second step is to determine the amount of loan the property will carry by fixing the net daily production owned by the applicant. Loans are never made on a single well because of the possibility of its going dry or making water, and the loans are calculated as a certain percentage of the prevailing price. The amount of the loan to be granted is then determined, and a formal application is prepared and submitted to the executive committee. After a loan is approved, the applicant furnishes the bank's attorney with the abstracts and has the title brought down to date. The applicant now becomes the borrower, and he mortgages to a trustee for the bank his interest in the property and also gives a chattel mortgage on his portion of the equipment. After the titles are cleared and abstracted properly, funds are disbursed under the mortgage.

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Employment Notices

The JOURNAL will post notices of men and jobs available. Companies and AIME members are invited to use this space, for which there is no charge. Address replies to: Code (appropriate number), JOURNAL OF PETROLEUM TECHNOLOGY, 601 Continental Building, Dallas 1. Show return address on envelope. These replies will be forwarded unopened, and no fees are involved.

PERSONNEL

♦ Graduate petroleum engineer, Missouri School of Mines, 31, married, six months electrical shop work, six months' experience with oil well service company; desires position with oil company in field. Code 116.

♦ Geologist, graduating with M.S. degree in February, 1950, 25, married; would like a position anywhere in the United States. Code 117.

♦ Petroleum geologist with B.S. degree, 32, married, 3½ years subsurface experience in Cuba and Venezuela; desires a position with a major company in the Mid-Continent, Rocky Mountain or Gulf Coast region. Code 118.

The first officers of the newly-formed South Plains Sub Section are L to R: David Morrison, George P. Livermore in Lubbock, secretary-treasurer; Cy Helm, The Western Co. in Levelland, 2nd vice chairman; W. D. Powers, Sid W. Richardson in Sundown chairman; and R. M. Leibrock, Stanolind in Lubbock, 1st vice-chairman.

Some of those who have been active in the organization work of the Sub Section are, L to R: Lee Flood, Production Management Co. in Midland; E. B. Armstrong, Honolulu Oil Corp. in Lubbock; Robert R. Shaffer, Stanolind in Levelland; Paul S. Johnson, P. E. Dept. of Texas Tech; and Joe Chastain, Bethlehem Supply Co. in Midland.

South Plains Sub Section Activities

By Robert R. Shaffer

Final organization of the South Plains Sub Section, Permian Basin Section, was completed with a meeting in Lubbock December 21, which was attended by approximately 60 AIME members and guests.

W. D. Powers, district engineer for Sid Richardson, Inc., in Sundown, was elected the first chairman. Other officers elected were: R. M. Leibrock, Stanolind Oil & Gas Co. in Lubbock, 1st vice chairman; Cy Helms, The Western Co. in Levelland, 2nd vice chairman; and D. B. Morrison, George P. Livermore in Lubbock, secretary-treasurer.

Directors elected for 1950 are: E. B. Armstrong, Honolulu in Lubbock, Paul Johnston, Petroleum Engineering Department in Texas Tech, and Robert R. Shaffer, Stanolind Oil & Gas Co. in Levelland.

Over 120 engineers in the South Plains area have expressed interest in belonging to the new Sub Section. While no definite geographical limits have been set, the South Plains generally includes the territory within a 50 to 75-mile radius of Lubbock. Membership in the Sub Section is offered to interested persons on a local basis, or a full membership in the AIME. Local members do not receive the Institute publications, and have no vote in the activities of the group, but they may attend all of the meetings.

The next meeting of the Sub Section will be held in Lubbock January 16. L. E. Young, president of the AIME, is expected to be present for the meeting. ★ ★ ★

New officers elected for 1950 are, L to R, Howard J. Rambin, Jr., vice-chairman, The Texas Co.; Fred E. Simmons, Jr., chairman, Louisiana Land and Exploration Co.; E. N. Van Duzee, vice-chairman, Shell Oil Co.; E. N. Dunlap, retiring chairman and director, California Research Corp.; and H. M. Krause, Jr., director, Humble Oil and Refining Co. Officers and directors not shown in the picture are: John Dillon, secretary, Shell Oil Co.; J. Randolph Gregson, treasurer, Rey Supply Co., Inc.; William Ilfrey, *Journal* secretary, Humble Oil and Refining Co.; and Earl Jipp, director, The California Co.

Delta Section Activities

By J. Paul Ratliff, Jr.

Guest speaker at the December 13 Delta Section meeting was W. H. Stewart, Sun Oil Co., Beaumont, Texas. Approximately fifty members enjoyed Stewart's presentation on the subject of gas-condensate well corrosion and participated in the group discussion which followed. After tracing the development of the NGAA and MC corrosion research program, Stewart stated that approximately 74 per cent of all corrosive gas-condensate wells reported by 29 operators are now being treated with chemicals. Also, the use of specially coated or alloyed sub-surface equipment is proving very satisfactory in the fight against corrosion. Stewart very ably responded to many detailed questions asked by the group. ★ ★ ★

Texas A&M Meeting

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produced for more than one year with a GOR of 4,200 to 1.

It was discovered that the gas section quit taking oil under hydrostatic head of the oil column, and the GOR started rising. The packers were raised out of the liner and flow secured through the entire sand section, and the packers re-lowered. To facilitate backflowing and to change the packer level, a hydrostatic lift arrangement was installed in surface equipment, illustrated in Fig. 3. It includes a walking beam type pump for pumping oil to the annular space between casing and tubing, and a sand filter through which all oil to casing is pumped. Also, it contains a worm gear mechanism for opening the port for back flowing the gas section of sand. The hydraulic lift is achieved by lifting the tubing by means of the polish rod. The tubing is held by slips 20 ft below the surface, operated by a lever. About 15 ft of tubing movement is possible with this equipment.

In concluding the paper, West reported on two other gravel-pack completions of the alternate layer type which produced good results.

A complete list of the other papers presented at the meeting, with the authors, is as follows:

Well Completion Fundamentals, H. T. Kennedy, A & M College of Texas.

Drilling Mud and Its Relation to Well Completions, E. H. Lancaster, Jr., Magnet Cove Barium Corp., and R. L. Whiting, A & M College of Texas.

The Jet Process of Open Hole Shooting and Casing Perforating, R. H. McLemore, Welex Jet Services, Inc.

Acidization in the Permian Basin, B. R. Weaver, Tide Water Associated Oil Co.

*Some Preliminary Investigations of Quantitative Interpretations of Radio-*Co. and E. S. Mardock, Well Surveys, Inc.

Diamond Bit Coring, Robert Todd, Core Laboratories, Inc.

Uses of Plastics in Sand Consolidation, Edward F. Kelly, Dowell Incorporated.

The Time Factor in Cementing, Bruce Barkis, B. & W., Inc.

Squeeze Cementing Operations, George Howard and C. R. Fast, Stanolind Oil and Gas Co.

"Hydrafrac" Process Results, W. D. Owsley, Halliburton Oil Well Cementing Co.

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Gulf Coast Section

Continued from Page 28

various treating agents used. Methods for treating limed muds have been developed in field practice, Goins stated, and little reason can be given for the particular techniques employed other than they work in practice. The purpose of this investigation was to develop a clearer understanding of limed mud systems.

He discussed the extent of calcium absorption by a bentonite or clay, which absorption depends upon the filtrate calcium concentration. Caustic used in limed muds serve to limit the solubility of the added lime and consequently the extent of absorption of calcium by the clays and bentonite. Where lime is used in high pH muds, the viscosity characteristics are such that the use of sufficient caustic to limit solubility of lime to the 60 to 120 ppm range results in minimum viscosity and thixotropic properties. Excess lime over that required for saturation serves as a reserve of lime to replace that taken from solution by shales dispersing into the mud during drilling. When caustic is not used and/or if other contaminants are present, higher filtrates calcium concentrations are obtained and other viscosity-filtrate calcium relations are shown. Filtrate calcium concentrations of over 200 ppm and sodium chloride concentrations of over two per cent are sufficient to exhibit a maximum inhibiting effect on hydration, and if carried in the filtrate, should result in less heaving shale, total solids and formation plugging difficulties.

In a prepared discussion, J. M. Bugbee, Shell Oil Co., pointed out the interesting property which limed muds exhibited in preserving shales. This property, he said, has been demonstrated by correlating caliper surveys with the use of these muds. Other prepared discussions on this paper were presented by Preston Chaney, Sun Oil Co., Beaumont, and John P. Weichert, Gulf Oil Corp.

Study Group Meeting

The second meeting of the newly organized Reservoir Engineering Study Group was held December 15 in the conference room of the Shell Research Laboratory. Approximately 50 engineers from Houston and surrounding areas were in attendance.

J. Daviss Collett, president of Associated Engineers, Inc., of Houston, spoke on the subject of techniques involved in securing and analyzing subsurface and recombined samples of reservoir fluids. Norman J. Clark of Humble introduced the speaker and acted as moderator for the discussion that followed. The many pertinent questions posed by members of the audience were capably answered by Collett and two of his associates, I. A. Jones and J. T. Ashford.

In line with the wishes of the members of the Group that the monthly programs be integrated in order to more efficiently cover the field of reservoir engineering, J. S. Levine, chairman, announced that the next meeting would be devoted to a discussion of the engineering treatment of PVT data obtained by the methods outlined by Collett.

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Junior Section Activities

Continued from Page 31

blow of a giant hammer. Obviously, this method is less expensive since it does not involve the drilling of shot holes. The seismic method is frequently used for offshore exploration and has been quite successful. The principle of seismic work under water is the same as it is on land except that hydrophones can be used in place of the conventional vibration instruments. The depth at which the explosive is detonated has a great bearing on the results obtained since if the explosive is set off too deep a large gas bubble forms which tends to compress and expand as it approaches the surface emitting unwanted shock waves. Seismic work in the search for limestone reefs, such as are found in Canada, has not met with success; however, this problem is currently being worked on.

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The Drift of Things

. . . as followed by EDWARD H. ROBIE
Secretary AIME

Council of Section Delegates

Among other features of the forthcoming Annual Meeting will be the first gathering of the newly organized Council of Section Delegates. Thus is another of the recommendations of the Committee on Divisionalization and Publication Program (Hjalmar W. Johnson, chairman, with M. M. Leighton and Clayton G. Ball) coming to fruition. This Committee suggested "some form of representative assembly serving as a co-ordinating link between Sectional units of organization and the Central Administration . . . The Council thus evolved should be made truly representative, with duly accredited delegates representative of the Local Sections, and possibly of the Divisions, possessing sufficient tenure of office to ensure continuity in its deliberations . . . It should function in an advisory capacity only . . . It would, in the first place, provide the electorate with orderly means of periodically informing the Directorate concerning membership views to a degree not now available, and in turn would provide the means by which the heavy responsibility and problems of the Central Administration could be better appreciated by the membership than is now often the case."

Following receipt of the Johnson Committee report, a "Committee on Democratization", consisting of Joseph L. Gillson, chairman, with Edmund A. Anderson and George B. Corless, was appointed to investigate the problem of democratization further and to activate the ideas of the Johnson Committee. It reported at the Annual Meeting in San Francisco last year, and one of its six points was the reorganization of the Section Delegates group and replanning of its meetings. The Committee was asked to amplify its suggestion, and at the September meeting of the Board, last fall, reported its recommendations in detail, offering provisional bylaws for the operation of the proposed Council. The forthcoming meeting will be organized and will operate under these bylaws.

Section Delegates' meetings are nothing new; they have long been on the program for our Annual Meetings. But heretofore the delegate has usually functioned as such for that meeting only; the agenda has been drawn up by the Secretary's office; the President of the Institute has presided; and the meetings have conflicted with technical sessions.

As envisaged by the Gillson committee, the principal duties of the new Council would be (a) To receive proposals, complaints, and suggestions from individual members or Local Sections. It may appoint committees to investigate such and to formulate recommendations to present to the Board. (b) To keep the President of the Institute informed on affairs in the Local Sections. (c) To receive information about Institute affairs from the Board through the President of the Institute and to pass such information on to Local Sections.

Each delegate will be elected for two years, but to assure continuity of at least half of the group the two-year terms will be staggered; that is, half of the Local Sections are appointing a delegate to serve until Nov. 14, 1950, and half a delegate to serve until Nov. 14, 1951. To get the meeting started next February, the delegate from the Colorado Section will be chairman pro tem, and the delegate from the Permian Basin Section, secretary pro tem. However, at the meeting, a Nominating Committee, consisting of the delegates from the Boston, Gulf Coast, and Pennsylvania Anthracite Sections, will report, offering a full slate of officers — chairman, vice-chairman, secretary, and four executive committeemen — who will, if elected, take office immediately.

The agenda for the meeting will be prepared by the delegates from the New York, Permian Basin, San Francisco, Upper Peninsula, and Colorado Sections.

Any Director or officer of the Institute may attend the Council's meetings as an observer, without vote, but only if invited.

Two meetings of the Council each year are authorized, but railroad expenses of the delegate will be paid only to the Annual Meeting of the Institute for the present. If a delegate cannot attend, an observer may take his place, or an observer may accompany a delegate, but an observer will in no case have a vote.

The Gillson committee suggests that "whenever possible the meeting shall precede by a day or so, a scheduled Board meeting." The Council meeting therefore has been scheduled for 10 a.m., Saturday, February 11, 1950, and it can continue through the afternoon and evening if need be. The Board will meet Sunday morning at 10, and all Section Delegates and observers are invited to be present and to participate in any discussion by the Directors of matters brought to the Board by the Delegates, or in other topics in which they may be interested. The meeting of the Council will be entirely free of any conflicting sessions, and the meeting of the Board largely so. Time should be sufficient for full discussion of important matters.

Some skepticism has been expressed as to whether the proposed plan will be more satisfactory than the procedure that has been followed before. But the mechanics are available for a true and uninhibited expression of the sentiment of the rank and file. The success of the meeting is entirely in the hands of the delegates.

Branch Organization

Another of the important recommendations of the Johnson committee was the organization of the Institute into three major technical groups — the Mining, Metals, and Petroleum Branches. With the organization of the Mining, Geology, and Geophysics Division now recognized, the Divisional structure is complete and the Branch organization can now be consummated. The bylaws of the Institute provide definitely for a governing council for each Branch, made up of at least six members, including one each from the Mineral Economics and Mineral Industry Education

Divisions, the other members being equally divided among the const'tuent Divisions. This means, in practice, that the Petroleum Branch council must consist of six or more members, the Branch and the Division here being synonymous; the Metals Branch council must consist of at least eight members (there being three divisions in the Branch); and the Mining Branch council may consist of six members or more (there being four Divisions in this Branch).

The Petroleum Branch council has already been set up and is the same as the officers and executive committee of the Petroleum Division; in fact, the Division prefers to be known as the Petroleum Branch. Likewise, the Metals Branch council has been named, with A. A. Smith, Jr., as chairman, E. O. Kirkendall as secretary, and an executive committee of six, including the chairmen of its three constituent Divisions. It is hoped that the Mining Branch council can be named at the Annual Meeting, at which time a meeting of the officers of the constituent Divisions is planned.

So far, the responsibilities and duties of the Branch councils have not been established, and this is a matter for early Board action. Certainly, general supervision over the Branch journals and the activities of component Divisions would seem to be within the province of the Branch councils. Fair appropriations from the national treasury for Divisional activities should be studied. One of the first responsibilities of the Mining Branch council which will be discussed at the Annual Meeting would presumably be to recommend to the Board whether or not a paid secretary should be employed, and if so, what his field of activity should be. The Johnson committee suggested a field secretary for the Institute as a whole, and the Gillson committee specifically recommended a field secretary for the Mining Branch, with headquarters preferably in Salt Lake City.

The Noble Prize

Honors, awards, and prizes bestowed by the Institute are becoming so numerous that many of them are not as well known to the membership as they deserve to be. The Alfred Noble Prize is an example. It is not strictly an AIME prize, since it may be granted to the author of "a technical paper of particular merit" published by any of the Founder Societies or by the Western Society of Engineers. However, AIME members have frequently won it, as they did in both 1948 (John H. Holloman) and 1949 (Robert L. Hoss). The cash prize is $350, and the expenses of the recipient are paid to the meeting at which the award is made. Competition for the prize is not severe, for it is limited to authors who have not passed their 31st birthday when the paper is accepted, and only a small proportion of the members of the societies in this category have reached the professional stature where they feel they can write an acceptable technical paper.

Here is an opportunity that should interest Junior Members, and those of our Members who are still in their twenties. The prize is decidedly worth while, as is the trip to the Annual Meeting, and the prestige of being the prize-winner may easily be worth considerably more than either, when it comes to looking for a job. All you have to do is to write a more outstanding paper than a dozen or so of your fellows. It's worth a try.

Continuing the Trip

In the November issue, the travels of the Secretary ended in El Paso on a rum note. This department got crowded out of the December issue, but the complaints thereby aroused by disappointed readers could have been counted by the Venus of Milo on the fingers of one hand.

From El Paso we drove to Silver City, New Mexico, where we found the small properties discouraged about the declining metal prices, but Kennecott's big open pit at Santa Rita was producing as usual, and a leaching project on some 125,000,000 tons of capping, containing about 0.35 per cent of copper, was underway, which should add a total of 400,000 tons to the country's copper production in the years to come. The ore for the concentrator runs a bit over 1 per cent in copper, about a tenth of which is oxidized. At the smelter at Hurley we found that the vibrating feeders on the reverberatories had been abandoned as they did not work satisfactorily on material containing around 9 per cent moisture.

Next stop, Inspiration, where we saw its open-pit operations for the first time, 15-yd Dart trucks (24 tons) dumping 5500 tons of ore daily direct to a 42-in. gyratory. An equal amount of waste has to be disposed of at present, but later on the waste should be but about 0.7 ton per ton of ore. At the leaching plant, capacity has had to be increased because of lower-grade ore. How was it done? By raising the walls of the leaching tanks 18 in., which increased their capacity by 12 per cent, but involved a big job in rearranging piping. We were interested in the grizzly bars being used in the belt discharge into the tanks to lessen segregation in the ore bed.

Sam Manuel is coming along as one of the country's biggest copper mines but there is not a great deal to see there as yet.

At Tucson we ran into a dads' and moms' day at the university, but T. G. Chapman had time for a good visit. Enrollment in the mining school there is at a peak and up a third over last year, with 216 undergraduates and 22 graduate students, though enrollment in the other engineering courses declined about 10 per cent, to 660. Particularly close relationships with the mining companies are maintained, which helps in getting jobs in the summer and after graduation, and in securing scholarships. Kennecott, for instance, maintains a $750 annual scholarship, AS&R one of $500, Shell $1500, Phelps Dodge a graduate scholarship of $1200. Interest on a $25,000 H. W. Oliver endowment goes to freshmen. Some 60 per cent of the mines enrollment is still GI's. The entire graduating class was placed last June at from $250 to $310 a month; one got $410. Dr. Chapman favors graduate work for metallurgists and geologists but not for miners. A course in labor relations, including a study of labor legislation, is now required for all except geologists.

At Ajo we found production at about 28,000 tons of ore per day, plus 20,000 of capping, all rail haulage just recently having been electrified, with Diesel electrics, and a 3 per cent grade. The chalcopyrite-bornite ore going to the mill runs but little over 0.8 per cent, with concentrate close to 30, and tailing less than 0.1. Arizona's newest copper smelter was under construction—a 360-ft stack and a reverberatory with Kuzell concentrate slingers to feed it. ★

1950 OFFICERS ELECTED AT NOVEMBER BOARD MEETING

With twenty Directors present, the Board again held a lengthy meeting on November 16, gathering for an informal luncheon at the Engineers' Club at 12:30 and moving over to the Board room at Institute headquarters immediately thereafter for a business session that lasted until 5:20. President Young presided, as he has at all Board meetings during his term of office.

T. W. Lippert, Manager of Publications, announced certain changes in the three AIME journals for 1950. The editor of each will select only those personals that he wishes to use, and the section of personals and obituaries common to all journals will be discontinued. All the items will be prepared at Institute headquarters as formerly but a selection will be made by each journal. This does not necessarily mean that each journal will limit its personals to items about the members of its own Branch, for it is expected that each editor will also carry the more important items about Institute members in other Branches as well. The reaction of readers is invited. To save space, the company connections and street addresses of applicants for membership are also being discontinued, and the possibility of complete elimination of the names of applicants is being studied.

Plans for increasing the advertising in all three journals were also announced. The JOURNAL OF PETROLEUM TECHNOLOGY will turn over advertising solicitation of new prospects in eleven Western states to the firm of McDonald-Thompson, of San Francisco and Los Angeles, and the mining and metals journal will appoint an advertising man with headquarters in Chicago, who may also be asked to solicit advertising in the petroleum journal. Final approval for the appointment of the Chicago representative was voted at the meeting of the Executive and Finance Committees on December 7.

Further attention was given by the Board to a matter that had come up at the October meeting of the Finance Committee: what to do about the Engineering Societies Building. Costly repairs are imminent and the building is inadequate to meet the needs of its occupants. The feeling of the committee that has been studying the matter, as reported in person by William N. Carey, chairman, and secretary of the ASCE, is that serious consideration should be given to securing, or constructing a new building and selling the present one. Many have also questioned whether or not the Founder Societies should continue to give the present substantial support to the Engineering Societies Library, and a home for this also enters into the picture. The United Engineering Trustees Real Estate Committee was encouraged by the Board to continue its study of the possibility of new quarters for the societies.

Official announcement was made of the election of the AIME officers presented by the Nominating Committee and published in the July issues of the journals. The ticket is headed by Donald H. McLaughlin as president for 1950, with Andrew Fletcher and Robert W. Thomas as vice-presidents, and Harold Decker, Francis B. Foley, E. C. Meagher, C. V. Millikan, Gail F. Moulton, and Howard I. Young, directors. Divisional chairmen, and directors ex officio for next year, are: Mining, Geology, and Geophysics, P. J. Shenon; Minerals Beneficiation, Grover J. Holt; Coal, Carroll F. Hardy; Industrial Minerals, Richard M. Foose; Institute of Metals, Maxwell Gensamer; Iron and Steel, H. K. Work; Extractive Metallurgy, Carleton C. Long; Petroleum, John E. Sherborne; Mineral Economics, Charles H. Behre, Jr.; and Mineral Industry Education, Allison Butts.

Some discussion was devoted to a recommendation of the Coal Division that the initiation fee for Members be reduced from $20 to $10, this would reduce AIME income from that source by about $9000 a year, which might be offset by the enrollment of a larger number of new members. It was thought that greater publicity should be given to the fact that the present initiation fee could be paid in four annual installments of $5 each on request, about 17 per cent of new members now taking advantage of this privilege. One suggestion was that no initiation fee be charged Junior Members when they must change their status to Associate or Member at age 33 but that the fee be charged in gradually increasing amounts, according to age, thereafter. It was decided to discuss the matter further at the Annual Meeting. How to handle the finances of Institute, Branch, and Divisional meetings, carrying out the idea that they should be self-supporting, also received attention by the Directors, with final decision to be made later.

The Mineral Industry Education Division was authorized to proceed with the implementation of its suggestion that a new major AIME award be given for notable contributions to mineral industry education. Approval was voted to the "Canons of Ethics for Engineers" adopted two years ago by the Engineers Council for Professional Development; the AIME had previously not subscribed to any such code. An invitation was presented for the AIME to suggest a candidate for the award of the Kelvin Medal in 1950 by the Institution of Civil Engineers, of Great Britain. The medal is given for "distinguished service in the application of science to engineering." The Secretary will be glad to have AIME members suggest names for this honor.

Appointments to committees authorized by the Board includes: Jack I. Laudermilk as vice-chairman of the Technical Publications Committee in lieu of Anthony Anable, resigned; Harold M. Bannerman on the Auxiliary Publications Committee of the Industrial Minerals Division, Oliver Bowles having declined; Francis B. Foley reappointed to represent AIME in the American Documentation Institute; James A. Barr to represent the AIME on the Committee on Deep Well Vertical Pumps, of the American Standards Association; A. Rodger Denison reappointed to represent AIME in the American Geological Institute; and O. B. Sawyer to take the place of C. H. Mathewson, resigned, on the Council of the American Association for the Advance-

ment of Science; Morris Muskat to represent AIME on the Committee on Fluid Permeation of the American Standards Association; and Manuel B. Llosa and A. Russell Merz to represent AIME at a meeting of the Peruvian Institute of Technical Valuations at Lima, December 8-15.

Sherwin F. Kelly reported on a meeting that he had attended as an AIME delegate — that of the First Pan-American Engineering Congress at Rio de Janeiro, July 15-23. He urgently recommended that AIME lend its wholehearted support to the continued existence of PAEC (UPADI) and take an active interest in the work of that organization.

Directors present, besides President Young, were: Alford, Benedict, Develer, Elkins, Head, Kinzel, Kraft, McLaughlin, Meyerhoff, Millikan, Peirce, Phillips, Rhines, Schumacher, Sullivan, Swainson, Swift, Williams and Wrather.

At a meeting of the Executive and Finance Committees on Dec. 7, with President Young and McLaughlin, Schumacher, Daveler, Weed and Fletcher present, various more or less routine and minor matters were disposed of. Approval was voted of a new Affiliated Student Society at the College of Engineering, New York University, with John N. Nielsen as Faculty Sponsor and Edmund M. Wise as Counselor.

The following prices were set on volumes in the Institute of Metals Symposium Series (superseding previous prices): Vol. 1, Nonferrous Melting Practice, and Vol. 3, Rod and Wire Production Practice, $2 to members and $3 to nonmembers; Vol. 2, Nonferrous Rolling Practice, $3 to members and $4.50 to nonmembers. ★ ★ ★

Proposed for Membership

Total AIME membership on Sept. 30, 1949, was 15,988; in addition 4427 Student Associates were enrolled.

ADMISSIONS COMMITTEE

James L. Head, Chairman; Albert J. Phillips, Vice-Chairman; George B. Carless, T. B. Counselman, Ivan A. Given, Robert L. Hallett, Richard D. Mollison, and John Sherman.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status; R, reinstatement; M, member; J, Junior Member; AM, Associate Member; S, Student Associate; F, Junior Foreign Affiliate.

ALABAMA

Tarrant—RUFF, WILLIAM B., JR. (M). Chief measurement supervisor, Southern Natural Gas Co.

ARKANSAS

El Dorado—RAGSDALE, JOHN G. (J). Division production engineer, Lion Oil Co.

Malvern—VINCENT, KENNETH CHAPMAN. (C/S—J-M). Chief metallurgist, Baroid division, National Lead Co.

CALIFORNIA

Avenal—KNOWLTON, DREXEL ROBERT. (R,C/S—S-M). Reservoir engineer, Kettleman Notre Dame Association.

Coalinga—HARRIS, DONALD FRED. (J). Petroleum engineer, trainee, Standard Oil Co. of Calif.

USTICK, RONALD ERROL. (J). Petroleum engineering technical assistant, Standard Oil Co. of Calif.

Glendale—LOCKWOOD, R. BRUCE. (M). Consulting geologist and engineer, Cole and Lockwood.

Los Angeles—MCMURRY, THOMAS RICHARD. (J). Sales engineer, A. O. Smith Corp.

SPARKMAN, RICHARD MYRON. (J). Field service engineer, Lane-Wells Co.

TOWNSEND, ROBERT DAWSON. (C/S—J-M). Equipment engineer, General Petroleum Corp.

WHITE, ROBERT THOMPSON. (M). Vice-president and geologist, State Exploration Co.

Menlo Park—HORN, ALVAH JORDAN. (C/S—J-M). Senior petroleum engineer, Standard Oil Co. of Calif.

Modesto—HOCKMAN, ALBERT BENJAMIN. (M). Chief petroleum and mud engineer, Rocky Mountain Drilling Co.

Riverdale—GRAVES, CHARLES DENNIS. (R, C/S—S-M). District superintendent, Amerada Petroleum Corp.

Taft—OLIPHANT, JOHN JOSEPH. (M). Production superintendent, General Petroleum Corp.

COLORADO

Denver—BUSH, HERBERT HOWARD. (J). Petroleum engineer, The Texas Co.

OWENS, MARVIN FRANKLIN. (C/S—J-AM). Chief petroleum engineer, The Bay Petroleum Corp.

ILLINOIS

Salem—HOCKMAN, JAMES NOAH. (M). Manager and geologist, Geophysical Consulting Service.

INDIANA

Augusta—HOLSAPPLE, LAWRENCE WILLIAM. (M). District engineer, Sinclair Oil and Gas Co.

KANSAS

Eureka—CAMPBELL, JAMES LESLIE. (C/S—S-J). Engineer trainee, Ohio Oil Co.

Garden City—MILLER, LOYLE POPE. (C/S—S-J). Trainee, Shell Oil Co.

Hays—ROGERS, ARTHUR MARION. (M). Station manager of Dowell, Inc., Hays, Kansas.

KENTUCKY

Henderson—MEFFORD, NACE FENNELL, JR. (C/S—S-J). Petroleum engineer, Ashland Oil and Ref. Co.

LOUISIANA

New Orleans—REYNAUD, RICHARD BURKE. (C/S—S-J). Rigman, Lane-Wells Co.

YEAGER, JOHN GLENN. (R, C/S—J-M). Gas superintendent, Humble Oil and Ref. Co.

MICHIGAN

Clare—BURGESS, DAVID MILLER, JR. (C/S—S-J). Petroleum engineer, geological survey division, department of conservation, State of Michigan.

NEW JERSEY

Cedar Grove—FAULKNER, ROSS HILTON. (M). Petroleum engineering consultant, Lehman Corp.

Nutley—PEREBINOSSOFF, ANDRE A. (M). Petroleum engineer (well logging specialist), Socony-Vacuum Oil Co., Inc.

Short Hills—KENNEDY, EDWIN L. (AM). Petroleum economist, Lehman Brothers.

Summit—MURPHREE, EGER VAUGHAN. (M). President, Standard Oil Development Co.

NEW YORK

Bronxville—LYON, EMMETT JEFFERSON. (M). Plants and pipeline operations analyst, Arabian American Oil Co.

New York—VAN PAASSCHEN, JACOB. (C/S—J-M). Reservoir engineer, The Texas Co.

OKLAHOMA

Bartlesville—BARTZ, MAHLON HUGH. (C/S—J-M). Metallurgical engineer, Phillips Petroleum Co.

WEY, JOHN EDWARD. (C/S—S-J). Petroleum engineer, P-I, U. S. Bureau of Mines, petroleum experiment station.

Duncan—LOWARY, THOMAS BLAINE. (J). Petroleum engineer, Magnolia Petroleum Co.

Norman—WOLBERT, GEORGE SMITH, JR. (C/S—J-M). Production engineer, Phillips Petroleum Co.

Oklahoma City—EISNER, STEPHEN M. (C/S—S-J). Petroleum geologist, Amerada Petroleum Corp.

JANOVY, JOHN. (C/S—J-M). District geologist, Tide Water Associated Oil Co.

Tulsa—DAVIS, WARREN B. (C/S—J-M). Production engineer, Gulf Oil Corp.

HALL, ALBERT LE CLAIR. (M). Valuation engineer, Deep Rock Oil Corp.

KAYE, EMBY. (M). Consulting engineer.

SCHLUNTZ, E. KENNETH. (C/S—J-M). Reservoir engineer (area), exploitation engineering division, production department, Shell Oil Co.

SOUTH DAKOTA

Philip—O'NEAL, LEWIS MERLE. (C/S—S-AM). Geologist, Cities Service Oil Co.

TEXAS

Bellaire—SIMPSON, RAYMOND ELLSWORTH, JR. (J). Associate engineer, Humble Oil and Ref. Co.

Dallas—COLES, BURTON EVERETT, JR. (J). Junior reservoir engineer, Atlantic Ref. Co.

COOK, EVIN LEE. (M). Research chemist, Magnolia Petroleum Co.

DAVIS, ROGER HUGH. (C/S—J-AM). Self employed, oil business.

FORT, ELLSWORTH WILLIAM. (R, C/S—J-M). Consulting petroleum engineer, Meyer and Achtschin.

HAYNES, JAMES MORTON. (M). Assistant manager, Engineer Sales and Service, Oil Well Supply Co.

JENKINS, RODMAN. (J). Research engineer, Magnolia Petroleum Co.

MITCHELL, JOSEPH AUGUSTUS. (AM). Assistant engineer (mechanical), research and development, Atlantic Ref. Co.

SCOTT, ERWIN RALPH. (R, C/S—J-M). Geologist, DeGolyer and MacNaughton.

Fort Worth—ROBINSON, REGINALD LAWRENCE. (AM). Engineer, Welex Jet Services, Inc.

Freeport—ELDER, HARVEY BERNARD, JR. (C/S—S-J). Petroleum engineer trainee, Ohio Oil Co.

Freer—PITTMAN, PITSER PAUL. (R, C/S—S-J). Production engineer, Edwin B. Cox and Jake L. Hamon.

Houston—WHITMORE, CLIFFORD MONROE. (M). Petroleum engineer, Stanolind Oil and Gas Co.

Kilgore—JAY, WILBURN REAGAN. (AM). Electrical well logging operator, Halliburton Oil Well Cementing Co.

Liberty—DRUSHEL, WILLIAM H. (C/S—J-M). District superintendent, The Texas Co.

Midland—LOOS, DE LASSO. (J). Corrosion engineer, Cool and Stilley Engineering Co.

WEST, ROBERT VAN OSDELL, JR. (J). Chemical engineer, Slick-Urschel Oil Co.

Odessa—GREENE, PAGE OSMOND. (C/S—S-J). Engineer, West Texas district, General American Oil Co. of Texas.

MAURICE, JAMES MATTHEW. (C/S—J-AM).

Orange—HOWARD, FORREST CONRAD. (J). Field engineer, The Texas Co.

Plains—CATLETT, R. JOHN. (J). District engineer, Texas Pacific Coal and Oil Co.

Sherman—SINCLAIR, THOMAS GRAHAM. (C/S—S-J). Field engineer, Standard Oil Co. of Texas.

Sunray—FORBES, FRANK HENRY. (C/S—J-M). Assistant chief engineer and field engineer, Continental Carbon Co.

Wichita Falls—GEARHART, MARVIN. (J). Junior engineer, Welex Jet Services, Inc.

WYOMING

Laramie—BIGGS, PAUL. (C/S—J-M). Petroleum engineer, U. S. Bureau of Mines.

LIPSTATE, PHILIP H., JR. (R, C/S—S-M). Petroleum engineer, U. S. Bureau of Mines.

VENEZUELA

Caracas—MEAD, HOMER NATHAN. (C/S—J-M). Senior petroleum engineer, Venezuelan Atlantic Ref. Co.

PATTON, WILLIAM RICHARD. (C/S—J-M). Sales engineer, Parkersburg Rig and Reel Co.

ROSALES, CESAR MIGUEL. (C/S—J-M). Exploitation engineer, Shell Caribbean Petroleum Co.

Maracaibo—FORRER, MARTIN. (J). Geologist, Texas Petroleum Co. ★ ★ ★

AIME MEETING CALENDAR

JANUARY

10 Delta Section, AIME. Water Injection

10 East Texas Section, AIME

11 San Francisco Section, AIME

16-19 Plant Maintenance Show. 4-day exposition and conference, Auditorium, Cleveland

17 Gulf Coast Section, AIME

18 Southwest Texas Section, AIME

FEBRUARY

8 San Francisco Section, AIME

12-16 Annual Meeting, AIME, Statler Hotel, New York City

14 Delta Section, AIME

14 East Texas Section, AIME

15 Southwest Texas Section, AIME

OCTOBER

4-6 Petroleum Branch, AIME, New Orleans

Book Reviews

Infrared Determination of Organic Structures

By H. M. Randall, R. G. Fowler, Nelson Fuson, and J. R. Dangl. D. Van Nostrand Co., Inc., New York, 1949. 239 pp., illus., charts, tables, diagrs., 8½ x 11 in., cloth, $10.

Reviewed by E. E. Bray, Magnolia Petroleum Co.

Empirical methods of infrared determination of organic structures are presented with the view of application to chemical analysis. The material in this text supplies some of the background which is required by the investigator, as well as adding substantially to the available information in this field. The instruments and techniques are described and methods of approach outlined for determination of structure. In addition to itemizing currently established correlations between structure and the absorption spectrum, a tabulation is made of the assignments of absorption bands of a large number of compounds containing double bonds. Also, the results of years of work on molecular structure are compiled in a form easily usable by nontheoretical chemists and physicists.

A reference library of the actual records of a great variety of compounds are reproduced and labeled with helpful information; however, one could desire that the spectrograms be corrected for the energy spectrum of the source.

Although not a complete treatment of the application of infrared spectroscopy to molecular structure, this book is a very worthwhile addition to any technical library. The book will serve as a very valuable reference manual to anyone engaged in the analysis of hydrocarbons and other organic materials by the methods of infrared absorption.

Natural Gas Economics

By Joseph A. Kornfeld. The Transportation Press, Dallas, 1949. 261 pp., diagrs., charts, tables, 9¼ x 6¼ in., leather, $5.00.

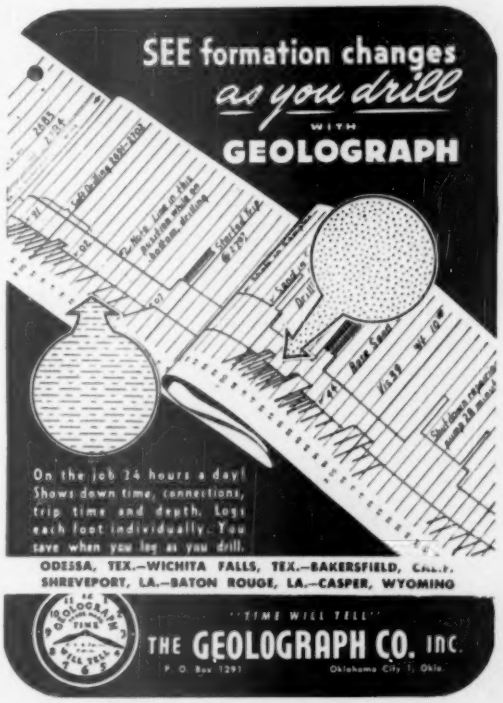
Reviewed by J. F. Dougherty, DeGolyer and MacNaughton.

This reference to the natural gas industry is primarily a compilation of published data for those whose knowledge of the industry is elementary. This is particularly true in regard to the chapters on "The National Economy", "Conservation", "Finance", "Reserves", and "Regulation".

"National Economy", "Conservation", and "Regulation" are treated by limited quotations from several published sources, primarily dealing with only the very broadest and most general aspects of the problems. The chapter on "Finance" is limited in scope by the unfortunate use of the Securities and Exchange Commission data on electric and gas utilities, rather than data on gas utilities alone. The case histories are inadequate, consisting of listings of Bonds and Stocks in expansion programs without relation to the company financing as a whole. Much of the statistical data is limited to the years prior to 1948.

The chapter on "Reserves" consists of descriptions of the Carthage, Hugoton, and Texas Panhandle fields, and the gas reserve estimates of the API and AGA. The summaries of field histories are adequate but marred by errors in abstracting and some miscorrelations and misconceptions where the author strays from the mechanical compilation. In ranking the Carthage field as a major field, comparison is made with a portion of the Texas Panhandle field, rather than the entire field. The topic of the proration formula is mentioned, but the formulae and method are omitted. The major role of the pinchout of permeability in the distribution of the producing zones of the Carthage field is not given due consideration. The data concerning the Hugoton field of Kansas, Oklahoma and Texas is actually limited in large part to only the Kansas portion of the field. Bottom hole pressures cited for the Hugoton field and Panhandle field are top hole shut-in pressures. The author has a tendency to utilize the ratio between reserves and current withdrawals or contract withdrawals to illustrate life expectancy of reserves, ignoring the physical ability of wells to produce and the effects of proration.

The chapter on "Price" starts out well with a summation of factors influencing wellhead and city-gate prices, but the statistical data is limited to the period prior to 1948 whereas the major price changes and impact of the factors listed have occurred since 1947. There are a number of useful tables in the chapters on "Demand", "Transportation, "Production", and "Finance", however, these items are outnumbered by charts and statistics of passing importance. The chapter on "Gas Storage" and "Synthetic Fuels" are interesting and well presented. Although the book is to a considerable extent a kaleidescopic compilation of previously published information it is none the less the fullest single presentation of the natural gas industry to date. ★ ★ ★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Paelfic Chapter

Continued from Page 29

source of energy. Material balance calculations have indicated that the current rate of water encroachment is approximately 1450 B/D. The current operating program for the pool has been designed to take full advantage of this water drive energy, and reservoir pressure has been substantially constant over the past three years.

Considerable work has been directed toward the effective control of water in this reservoir and the plugging operations conducted to date have been very successful. The performance of the wells is characterized by an initial production period of approximately 100,000 bbls of oil with an average cut of less than 1.0 per cent, followed by a relatively short period during which the water cuts increased at a progressively more rapid rate until an average of 50 per cent was reached whereupon plugs were placed in the wells. In almost all the wells it was found that bottom water was responsible for the water entry and that subsequent to plugging operations the cuts dropped to a value equal to or below the original cut figure.

Subsequent to the initial flowing life of this reservoir, the production has been obtained almost exclusively by intermittent gas lift through inch and one-half tubing. A comparison of the cost of producing with this method of artificial lift with that which would have resulted if pumping equipment had been utilized indicates that the gas lift operations have resulted in a saving of approximately 50 per cent. It should be kept in mind, however, that these results apply only to producing conditions which have been encountered in this particular reservoir up to the present time. In addition to this large saving in operating costs the gas lift system has been most advantageous from the standpoint of flexibility in controlling withdrawal rates from individual wells and in operating the various instruments for obtaining reservoir information. It is believed that higher ultimate recovery will probably be obtained from the reservoir than if there had been no control of withdrawal rates as governed by engineering application of reservoir information.

The general discussion following the presentation of the paper was concerned primarily with the desirability and possible economic value of re-injecting the produced water into the reservoir. This process has been given some considerable study and appears to be primarily dependent on economics, and thus subject to the changing aspects of price and costs.

Committee Chairmen

The Council of the Pacific Petroleum Chapter met December 4 to plan activities for 1950. Committee members were chosen and a tentative schedule for field trips and the fall meeting were formulated. The appointments for the regular offices are as follows:

Secretary-Treasurer, Ray Hancock, Lane-Wells Co.; JOURNAL Secretary, I. A. Marshall, Shell Oil Co., Long Beach; Field Trip Chairman, not yet selected; Forum Chairman, Charlie Dodson, University of Southern California; Luncheon Meeting Chairman, Ed Galvin, Western Gulf Oil Co.; Membership Chairman, Charles McClure, Youngstown Steel Products. ★ ★ ★

...need we say more?

FRANKLIN D. COOPER
321 Lansdowne Road
DE WITT, NEW YORK

Consulting Engineer

August 9, 1949

Telephone Syracuse 72-2190

American Paulin System
1847 South Flower Street
Los Angeles, California

Gentlemen:

On July 9, 1949, I made an altimeter survey of the Susquehanna River and Owego Creek at Owego, N. Y. This preliminary survey was made in connection with the Owego, N. Y., Flood Control Project.

The Village of Owego had run a line of levels several miles along the low water line of the Susquehanna River. In spite of unfavorable weather, your latest model Micro surveying altimeter checked the levels run by the Village of Owego within a foot.

I am convinced that your latest Micro altimeter is equivalent in precision to the finest theodolite.

In connection with the above altimeter survey, I was only able to get readings from the local weather bureau office to the nearest 5 ft. I would therefore like to purchase a second Micro altimeter to be read every 10 minutes.

You may be sure that I am telling all of my associates of the performance of your fine instrument.

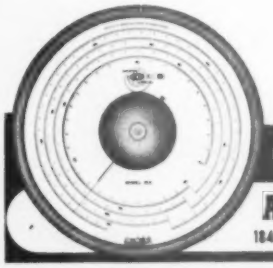
The workmanship on your instrument is as fine as I have seen on any instrument anywhere.

I was amazed at the performance of your instrument; and you may be sure that wherever I use it, I will recommend it wholeheartedly.

Very truly yours,

F. D. Cooper

Franklin D. Cooper, P. E.



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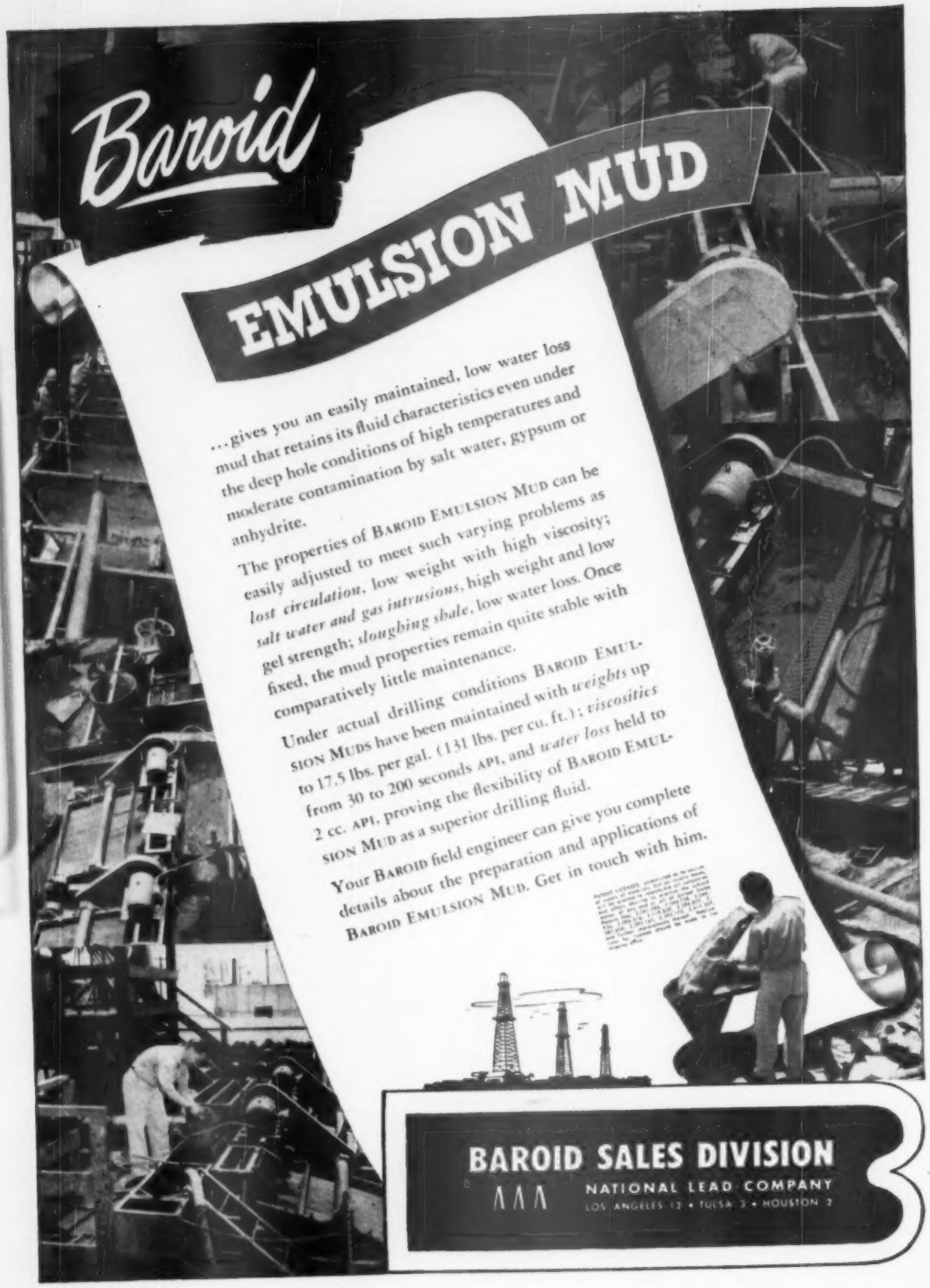
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PHASE EQUILIBRIA IN HYDROCARBON-WATER SYSTEMS

The Solubility of Ethane in Water at Pressures to 1200 Pounds Per Square Inch

O. L. CULBERSON, THE UNIVERSITY OF TEXAS, AUSTIN, **ALBERT B. HORN,** ETHYL CORP., BATON ROUGE, LOUISIANA, AND **J. J. McKETTA, JR.,** THE UNIVERSITY OF TEXAS, AUSTIN, MEMBER AIME

ABSTRACT

Since water is present in natural gas and petroleum reservoirs, it is of engineering value to have accurate experimental data regarding the behavior of water in hydro-carbon systems. Since experimental data of this nature are so scarce in literature, a program is under way at the University of Texas to obtain experimental data regarding the distribution of water in petroleum hydrocarbons.

This initial paper is subdivided into three parts:

A. The apparatus and analytical procedure are discussed.

B. The equipment has been checked by comparing the experimental data with data of literature on the solubility of methane in water at 77°F and pressures to 10,000 psia.

C. Experimental data are presented at 100, 160, 220, 280, and 340°F on the solubility of ethane in water at pressures to 1200 psia. As the temperature is increased the solubility of ethane in water first exhibits a minimum and then a maximum solubility. The range of applicability of Henry's Law is discussed.

INTRODUCTION

Although considerable experimental data have been published on water-hydrocarbon systems in the hydrate region, the information on these systems in the vapor-liquid and the vapor-liquid-liquid regions at elevated pressures is extremely scarce. A survey of the literature on hydrocarbon-water systems at elevated pressures was presented by McKetta and Katz[12,13,14] showing the systems and phases investigated. In addition to these existing published data, Poettman and Dean[15] have reported the water content of propane in the three-phase region (only the propane-rich liquid and the vapor phases were studied) and Michels, et al.[16] have reported the solubility of methane in water at pressures to 6800 pounds per square inch at 77°F and at pressures to 1500 psia at temperatures to 300°F.

It has been shown[17,14] that the presence of water will materially affect the phase equilibrium of hydrocarbon systems. In order to make experimental studies on the quantitative effect of the presence of water in naturally-occurring hydrocarbon systems, it is desirable to have data available on binary hydrocarbon-water systems.

A program is underway at this laboratory to determine the phase relations of the hydrocarbon-water systems. Initially the investigation will be limited to binary systems with water as one of the components. Later ternary and complex systems will be investigated and reported.

EQUIPMENT AND ANALYTICAL PROCEDURE

Apparatus

In order to avoid a description of the methods employed in each subsequent paper, a description of the apparatus and the analytical procedure will be given here. The apparatus is shown schematically in Fig. 1. The numbered items in Fig. 1 represent the high pressure valves.

The equilibrium cell is of the totally enclosed type, with a volume of 550 cubic centimeters. The cell is mounted in an air bath which in turn is mounted on pillow blocks and connected to a rocking mechanism so that the cell and bath will oscillate approximately 30 degrees above and below the horizontal at 35 oscillations per minute.

The air bath is heated by two resistance heaters. The first or primary heater is 250 watts and is controlled by a thermoregulator; the second heater is of 500-watt size and is manually controlled to aid in bringing the cell to equilibrium temperature. Air circulation in the bath is accomplished by means of a fan, the shaft of which is concentric to the heaters. The walls of the bath are insulated with 2-in. thick blocks of 85 per cent magnesia. Temperature observations are made with three calibrated thermocouples. One couple is sealed in a well provided within the equilibrium cell, and is used as the criterion of the cell being at the equilibrium temperature. The other two thermocouples are located on opposite sides of the cell to indicate temperature uniformity within the air bath. The thermoregulator, used in conjunction with a relay, gives a variation in the temperature of the air in the bath of plus or minus one degree Fahrenheit. However, since the equilibrium cell weighs approximately 55 pounds, the

[1]References are given at end of paper.

Manuscript received at the office of the Petroleum Branch August 31, 1949.

temperature sine curve which exists in the bath is so dampened by the cell that no temperature fluctuations in the cell can be detected with the semi-precision type potentiometer used.

The tubing used in the equipment is 18-8 stainless tubing with an outside diameter of ¼ in. and an inside diameter of 3/32 in. Valves and tees are of the super-pressure type.

Three pressure gauges are connected to the equilibrium cell to determine the pressure conditions within the cell. These gauges (Ashcroft Duragauge) have 12-in. dials and are of the pressure ranges 0-1000, 0-5000 and 0-10,000 psia. Only one gauge is used at one time depending upon the pressure within the equilibrium cell. These gauges are calibrated at intervals with a dead weight gauge and at no time have these gauges deviated from the preceding calibrations.

A stainless steel bomb of 365 cubic centimeters capacity is used as the water surge and a low carbon steel bomb of 710 cubic centimeters capacity is used as the hydrocarbon surge bomb. Each surge bomb is equipped with a pressure gauge to indicate the pressure within the bombs. Within the system, material is pumped to the desired places by means of a converted 20-ton hydraulic jack of the Walker type. The fluid used in the pump is additive-free heavy mineral oil which is pumped to a mercury-oil surge where the oil displaces mercury into the system. The mercury-oil surge is equipped with an electric contact mechanism which causes a bell to ring when the mercury interface is within three inches of the bottom of the mercury-oil surge bomb. There is no indication that the oil is leaking with the mercury from the bottom of the mercury-oil surge.

In making a solubility determination, the cell is first charged with the hydrocarbon vapor to a pressure about one-half of that desired for the equilibrium pressure. Water is then pumped into the cell from the liquid surge until the pressure is approximately the equilibrium pressure. The liquid volume is then approximately one-half of the total volume of the equilibrium cell. All tubing leading to the cell is then pumped full of mercury. The heaters are turned on and the rocking mechanism is started. After the contents of the cell reach the desired temperature, the oscillations are continued for a minimum of three hours. Some preliminary time-concentration experiments indicated that less than one hour of oscillation is required to attain equilibrium within the cell.

At the end of three hours of rocking, the cell is placed in a vertical position and the liquid portion of the cell is sampled and analyzed. Valves (8) and (10) are opened slowly until all of the mercury is removed from the tubing. At the same time, mercury is pumped into the cell to maintain the equilibrium pressure. As soon as all of the mercury is removed from the tubing, valve (10) is closed and valve (9), which leads to the analytical train, is opened.

Analytical Procedure

The analytical train is shown in Fig. 2 and is composed of a trap for collecting the liquid water, three drying tubes containing magnesium perchlorate

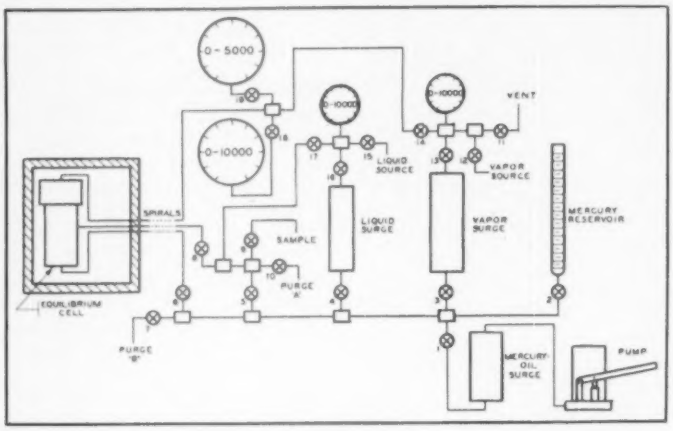

FIG. 1 — DIAGRAM OF APPARATUS

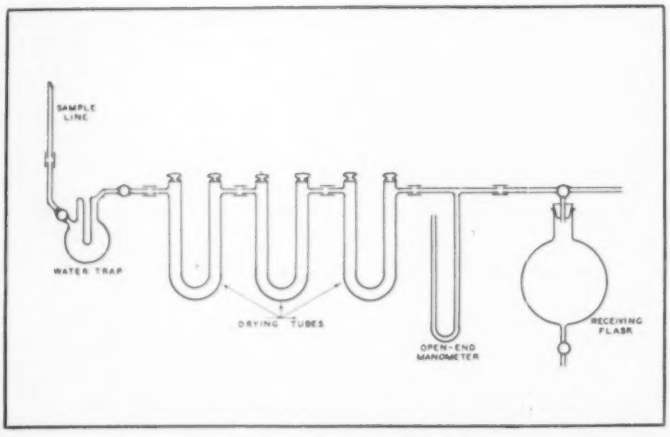

FIG. 2 — ANALYTICAL APPARATUS

to collect water vapor leaving the trap, and a receiving flask in which the dry hydrocarbon vapor is collected over mercury. A manometer and thermometer are also part of the train.

Before the train receives the sample, the water trap and drying tubes are weighed on an analytical balance while they are filled with hydrocarbon vapor at a known temperature and pressure. The receiving flask is filled with mercury up to the three-way stopcock. The train is then reassembled and connected to the equilibrium apparatus. It may be added here that it was necessary initially to pass considerable predried pure hydrocarbon through the drying tubes until they attained a constant weight. This indicated that some hydrocarbon vapor was adsorbed by the drying agent.

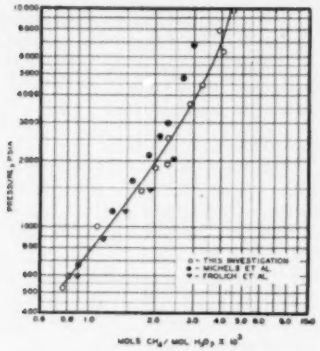

FIG. 3—SOLUBILITY OF METHANE IN WATER AT 77°F AT PRESSURES TO 10,000 PSIA

The sample is passed from the equilibrium cell through valve (9) to the train and at the same time mercury is pumped into the cell to maintain the equilibrium pressure. As the sample passes valve (9), it flashes to atmospheric pressure and this pressure reduction causes most of the hydrocarbon vapor to flash out of solution. The water, saturated with hydrocarbon vapor at this low pressure, is collected in the trap and the wet gas passes through to the drying tubes, and from there the dry gas passes to the receiving flask. By gradually removing some mercury from the receiving flask, the pressure in the train is maintained at the predetermined near-atmospheric pressure. When the trap is filled (approximately 50 cc of the water-rich liquid) the sampling is stopped. The analytical train is then brought to the initial temperature and pressure conditions.

The weight of the vapor hydrocarbon in the sample is that weight which would occupy a volume at the train pressure and temperature equal to that of the volume of the mercury displaced from the receiving flask less the volume of the water-rich liquid which entered the train. The total weight of the hydrocarbon is the weight of the vapor hydrocarbon plus the weight of the hydrocarbon remaining in solution in the water-rich liquid in the trap. This latter weight of hydrocarbon can be calculated from the solubility data of Winkler[10] at atmospheric pressure. The weight of the water in the sample is the weight of the water in the trap plus the water-gain of the drying tubes.

Accuracy

The weighings are made on an analytical balance with perfect tares using weights which were calibrated against the National Bureau of Standards weights. The temperature of the material within the cell is determined with a calibrated thermocouple and no fluctuation of the temperature is indicated with a semi-precision potentiometer. The pressures are read from the calibrated bourdon gauges and it is believed that the pressures are within the following accuracy on the individual gauges: Below 1000 psia, ±3 psia; between 1000 and 5000 psia, ±10 psia and between 5000 and 10,000 psia, ±20 psia.

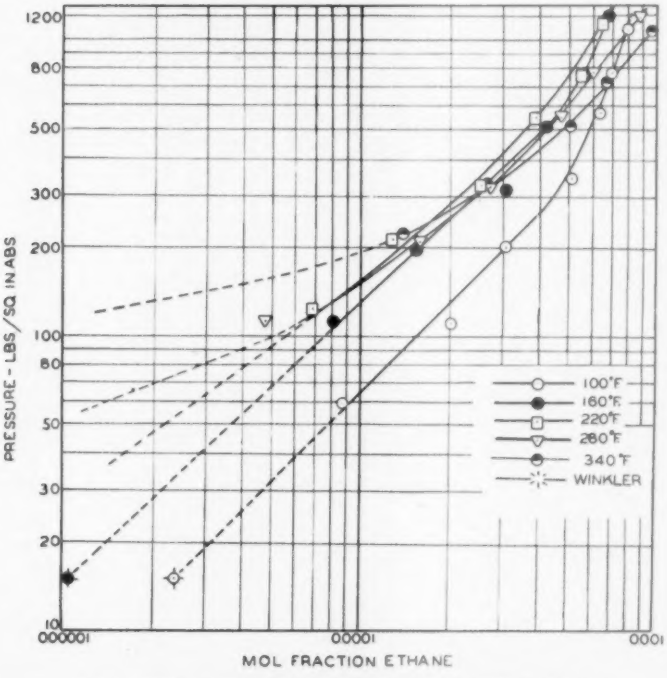

FIG. 4 — EFFECT OF PRESSURE ON THE SOLUBILITY OF ETHANE IN WATER

SOLUBILITY OF METHANE IN WATER AT 77°F AND PRESSURES TO 10,000 PSIA

In order to check the apparatus, operating procedure and analytical technique it was decided to determine the solubility of methane in water at 77°F, since these data have been reported by Michels, et al.[13] for pressures to 6800 psia and by Hogan[7] and Frolich, et al.[3] for pressures to 2060 psia.

The data obtained in this investigation are shown in Table I along with the data of the investigators mentioned above. The data of Hogan are included in the paper of Frolich et al. These data of Table I are shown graphically in Fig. 3 and it may be seen in this figure that there is substantial agreement in all three investigations. The data of this investigation lie between those of Frolich and Michels. Hogan indicates in his thesis that he was interested in practical results and also states that he made no attempt to obtain precise data. Therefore little concern arises from the deviation of the data obtained in this investigation from those data of Hogan. Michels and his coworkers obtained their results by using a method which they class as a "synthetic" one. The liquid is brought into contact with the gas, shaken until equilibrium has been attained and calculating the amount of gas dissolved by noting the decrease in pressure. The method of calculating the solubility was that suggested by Krichevsky and Kasarnovsky[9]. Since Michels and his co-workers started at a low pressure, attained equilibrium, calculated the solubility, added more gas to attain a higher pressure, again attained equilibrium and again calculated the solubility at the new pressure, it seems very likely that any error resulting from the original set of equations[9] because of the assumptions made for low pressure conditions would be cumulative. Therefore it is not at all surprising that there is over 20 per cent deviation of Michels data when compared to the data of this investigation. It is remarkable, however, that the data agree as well as they do, especially at these concentrations.

SOLUBILITY OF ETHANE IN WATER

There are no data in the literature on the solubility of ethane in water at elevated pressures. The data of Winkler[10] are universally accepted as being accurate; however, these data, while at various temperatures, are only for atmospheric pressure.

The work reported here consists of an experimental investigation of the water-rich liquid phase of the ethane-water system at 100, 160, 220, 280, and 340°F and pressures to 1200 pounds per square inch absolute (psia). Since the lowest temperature of this investigation is above the critical temperature of ethane and above the hydrate forming temperatures at these pressures, only two phases were present at any time during this investigation.

Experimental Results

Upon investigation of the compressibility factors for ethane, it is readily seen that ethane departs from ideality at pressures lower than 1200 psia.[1] This, coupled with the fact that water is a highly polar compound, indicated that the system would depart from ideality and would deviate considerably from Henry's law.[4,5]

The experimental data obtained in this investigation are given in Table II.

Table I
Solubility of Methane in Water at 77°F (25°C)
(Moles Methane Per Mole Water)

Pressure psia	This Investigation Experimental	This Investigation Smoothed	Michels[16]	Frolich[7]
296				0.000665
525	0.000770	0.000750		
589		0.000825	0.00081	0.000887
666		0.000910	0.00090	
880		0.00112		0.00118
1000	0.00110	0.00123		
1175		0.00139		0.00148
1180		0.00140	0.00128	
1450	0.00180	0.00162		
1465		0.00163		0.00192
1623		0.00175	0.00158	
1845	0.00202	0.00191		
1930	0.00227	0.00198		
2115		0.00210	0.00187	
2060		0.00206		0.00244
2535	0.00231	0.00235		
2560		0.00237	0.00210	
2970		0.00260	0.00229	
3615	0.00288	0.00293		
4435	0.00328	0.00325		
4800		0.00337	0.00269	
6342	0.00407	0.00380		
6800		0.00391	0.00298	
7935	0.00391	0.00412		
9680	0.00451	0.00434		

Table II
Solubility of Ethane in Water

Temp. °F	Pressure psia	Mole Fraction Ethane x 10^4 Experimental	Mole Fraction Ethane x 10^4 Smoothed	Per Cent Deviation
100	59	0.893	0.930	+4.15
100	110	2.04	1.730	-5.20
100	200	3.11	3.11	0.00
100	340	5.21	5.00	-4.01
100	568	6.47	6.39	-1.23
100	767	7.09	7.20	+1.55
100	1080	8.01	8.01	0.00
160	113	0.812	0.850	+4.69
160	196	1.54	1.54	0.00
160	315	3.09	2.55	-17.55
160	512	4.17	4.21	+0.96
160	785	5.70	5.64	-1.05
160	1215	6.79	6.79	0.00
220	123	0.698	0.750	+7.45
220	212	1.30	1.47	+13.1
220	322	2.56	2.42	-5.47
220	548	3.91	3.91	0.00
220	752	5.60	5.20	+7.14
220	1120	6.61	6.70	+1.36
280	113	0.475	0.530	+25.00
280	210	1.58	1.56	-1.27
280	320	2.72	2.72	0.00
280	557	4.64	4.64	0.00
280	785	6.00	6.10	+1.67
280	1215	8.65	8.65	0.00
340	226	1.40	1.42	+1.43
340	334	2.61	2.75	+5.36
340	529	5.03	4.90	-2.58
340	742	6.71	6.82	+1.64
340	1140	9.70	9.70	0.00

Fig. 4 shows the effect of pressure on the solubility of ethane at 100, 160, 220, 280, and 340°F, and plotted as mole fraction of ethane versus total pressure of the system. Since ethane exhibits a minimum and maximum solubility in water at the temperatures and pressure covered by this investigation, it is difficult to visualize the trend of solubility from Fig. 4. For this reason these data are cross-plotted in Fig. 5 which shows the effect of temperature on the solubility of ethane in water and clearly indicates the minimum and maximum trends. The data for Fig. 5 were obtained by interpolating values from the smoothed curves of Fig. 4. The minimum and maximum in solubility illustrated here is not uncommon; these phenomena have been reported in various systems[7,9,9,10,14,18] and have been explained by Winkler[19] and Kuenen[18] as a neutralization effect of the opposing factors of viscosity and the thermal expansion of the liquid. Winkler showed that the solubility of a gas in water is zero at a total pressure equal to the vapor pressure of water.

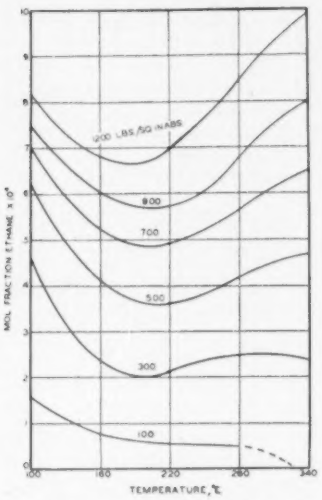

FIG. 5 — SOLUBILITY OF ETHANE IN WATER EXHIBITING MINIMUM SOLUBILITY

Fig. 6 shows the solubility of ethane in water, plotted as volume of ethane per unit volume of water, both components referred to 32°F and a pressure of 760 mmHg[11,18]. Fig. 6 demonstrates the range of applicability of Henry's law to this system. It is seen that temperature has considerable effect on the maximum pressure to which Henry's law may be applied. The maximum pressure at which Henry's law would apply for the various isotherms is as follows: 100°F, 300 psia; 160°F, 600 psia; 280°F, 600 psia; 280°F, 400 psia; 340°F, 400 psia. The relatively high pressure at which Henry's law is applicable for the 160 and 220°F isotherms can possibly be explained as the effect of the factors previously mentioned; viscosity and thermal expansion of the liquid. Above 220°F the maximum pressure limit for the application of Henry's law is seen to decrease. This agrees in part with the data of McKetta and Katz[18]; however, the effect of temperature in their system was not so marked as in this investigation.

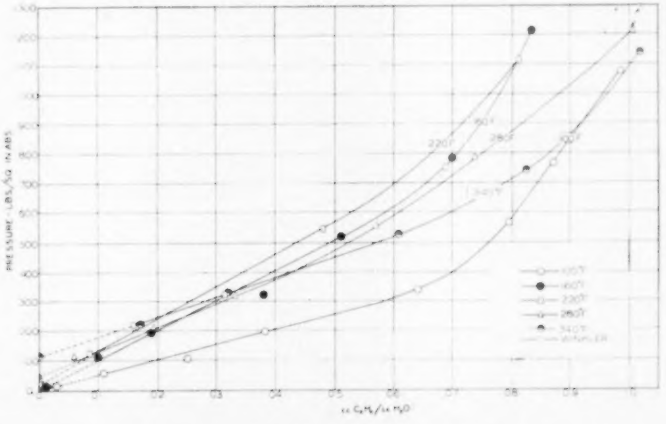

FIG. 6 — VOLUMETRIC SOLUBILITY OF ETHANE IN WATER

Fig. 7 is a comparison of the data of this investigation with similar systems at 100°F[3,15,18]. The data of Frolich[3] are for the solubility of methane in water at 77°F, and are included here rather than the data of Michels[15], although the latter data are available at 100°F, because only two (of Michel's) experimental points fell within the range of this investigation.

It is interesting to note that the solubilities of the hydrocarbons tend to converge at a pressure of 200 psia. The solubility of methane-n-butane[14], however, is essentially the same as that of methane in water[3]. It is also interesting to note that the solubility of hydrogen in water is in the same order of magnitude.

Although the data presented here are expressed in terms of mole fraction ethane, there is no essential difference between mole fraction and mole ratio for the data determined in this investigation. This is due to the fact that the difference between mole ratio and mole fraction for this low solubility lies outside the accuracy of the data.

Materials

The methane used in this investigation was donated by the Phillips Petroleum Co. and has a purity of 99.0 mole per cent minimum. No attempt was made to purify the methane further.

The ethane was also donated by the Phillips Petroleum Co. and was certified by the National Bureau of Standards to have a minimum purity of 99.99 mole per cent.

The water used in this work was obtained from the distilled water supply of the chemical engineering department. This distilled water was boiled to remove dissolved air from solution.

ACKNOWLEDGMENT

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2. The Phillips Petroleum Co. for furnishing the methane and ethane.

3. The president of the University of Texas for furnishing a special research grant to initiate this investigation.

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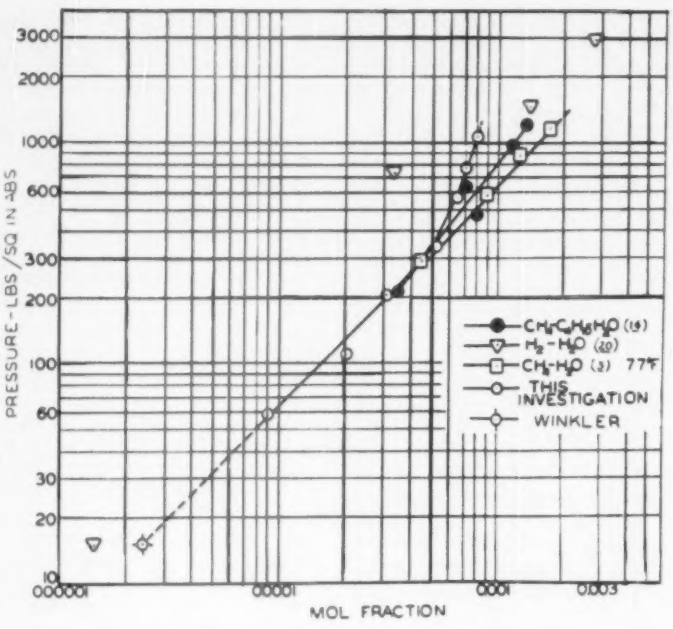

FIG. 7 — COMPARISON OF LABORATORY DATA WITH LITERATURE AT 100°F

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LAKEVIEW POOL, MIDWAY-SUNSET FIELD

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ABSTRACT

The Lakeview Pool of Kern County, California, was discovered in 1910 with the drilling of Lakeview No. 1 which blew out and produced an estimated 8,250,000 bbl of oil in 544 days of uncontrolled flow. The well has since been known as the Lakeview Gusher. Full exploitation of the pool did not take place until about 25 years later. A total of 112 producing wells were completed in the Lakeview sand through April 30, 1949. As of that date, about 30 per cent of the total wells drilled were still producing, with an average pool production rate of approximately 2000 bbl per day. The cumulative oil production was about 41 million bbl of oil, or 55.3 per cent of the tank oil originally in place.

The pool is bordered on its downstructure side by a body of inactive edgewater and water production where present has been principally the result of coning.

Since the depletion of the greater portion of the gas energy by the Lakeview Gusher, the pool has operated under gravity drive. Relatively high angle dips, good permeabilities and favorable fluid characteristics have made gravity drainage particularly effective. Since January, 1942, the oil recovery has been relatively constant at about 53,000 bbl per ft drop in fluid level. Correlations between the volume of reservoir space drained and the cumulative oil produced indicate that an ultimate recovery of 63.3 per cent of the tank oil originally in place is attainable.

INTRODUCTION

The Lakeview Pool is an outstanding example of gravity drainage. It is one of many productive reservoirs of the Midway-Sunset Field, and is located in Kern County, approximately five miles southeast of Taft and two miles north of Maricopa, California. Its position relative to surrounding pools and to the Thirty-Five anticline is shown on Fig. 1. The northern portion of the pool lies in sections 32 and 33, Township 32 South, Range 24 East, Mt. Diablo Base and Meridian, while the southern portion lies in sections 25, 26, 35 and 36, Township 12 North, Range 24 West, San Bernardino Base and Meridian. As no two sections bear the same number, they will hereafter be referred to by section number alone.

The purpose of this paper is to review the performance of the Lakeview Pool in an effort to evaluate the effectiveness of gravity drive as a recovery mechanism.

REGIONAL STRATIGRAPHY AND STRUCTURE

The oustanding structural feature in this area is the Thirty-Five anticline, the axis of which plunges South 75° East through the center of Section 35. As shown on Fig. 2, the following zones are oil and gas bearing in the Thirty-Five anticline area:

Pleistocene
- Basal Tulare
  - Tar Sands

Pliocene
- San Joaquin
  - Mya Sands
  - Top Oil or Scalez Zone
- Etchegoin
  - Kinsey Sand
  - Wilhelm Zone
  - Gusher Sand
  - Calitroleum Sand

Miocene
- Reef Ridge
  - Lakeview Sand
  - Sub-Lakeview Miocene Sands
  - Monarch Sands or fractured shale equivalent
- Maricopa
  - Webster Sand or fractured shale equivalent
  - Fractured Shale-Uvigerina Zone C
  - Obispo Sand and fractured shale equivalent
  - Pacific Shale Zone

The productive interval of the Lakeview Pool is limited to Upper Miocene and Lower Pliocene deposition. In this general area, the most prevalent type of accumulation results from stratigraphic traps or permeability pinchouts. As is the case of the Lakeview Pool, stratigraphic traps resulting from angular unconformities are present. The structure within the Miocene does not parallel that of the Etchegoin (Pliocene), as the Miocene beds were folded, and in places faulted, and subjected to erosion prior to Pliocene deposition.

The Lakeview horizon consists of truncated sands which occur on the northeast flank of the Thirty-Five anticline. The direction of strike is west and northwesterly through sections 25 and 36 and continues northwesterly through sections 26 and 33, to the approximate center of section 32. At this point the strike swings to the northeast and the horizon re-enters section 33, in the northwest corner. The change in strike in section 32 affords synclinal accumulation at that point. The Lakeview sand is truncated updip by the Etchegoin overlap. To the southeast, the sand shales out, while to the northwest, the productive interval appears to be limited by a combination of stratigraphic pinchout and permeability barrier.

Structurally, the Lakeview reservoir presents three areas of interest, as shown on Fig. 3. Area I in section 32 is a region in which a productive Sub-Lakeview Miocene sand is present. It occurs from 10 feet to 30 feet below the base of the Lakeview sand and attains a maximum thickness of 25 feet in Well No. 21, section 32. The producing characteristics of the Sub-Lakeview Miocene sand differ radically from those of the Lakeview sand. Water production at high structural locations and abnormally high fluid levels indicate that there was no communication with the Lakeview sand. Wells in Area I penetrated this sand and produced it in conjunction with the Lakeview sand.

In Area II, the Lakeview sand is a

[1] References are given at end of paper.

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relatively continuous Miocene sand body unconformably overlain by Etchegoin (Pliocene) sediments. It is overlapped upstructure and apparently shales out downstructure, although downstructure production is limited by an inactive edgewater.

In Area III, the Lakeview sand is broken into two fingers by an intermediate Miocene shale body. In addition, a productive Etchegoin sand, the Calitroleum, overlies the Miocene Lakeview sand, being separated from it by an intermediate Etchegoin shale. This structural relationship is shown in Fig. 4. In this area all wells exposed to the Lakeview sand also include the Calitroleum sand. The Calitroleum sand lenses out along the west boundary of this third area as a result of an unconformity at the top of the Lakeview sand. Downstructure production is limited by inactive edgewater in both the Lakeview and Calitroleum sands. To the east these sands feather into shales. Due to the similar production characteristics of both the Calitroleum and Lakeview sand fingers, these productive sands, for the purpose of this report, have been designated as Lakeview sand and will hereafter be referred to as the first, second and third fingers of Lakeview sand.

Fig. 5 is a subsurface structure map contoured on the top of the Lakeview sand. The productive limits of the pool are delineated by a line of zero net productive sand thickness. The change in strike direction in section 32 is accompanied by a change in dip. The dip varies from 7.3° along the synclinal axis in section 32 to a maximum of 31.0° in section 33. An average of individual dips at 250′ intervals along strike is 24°.

DEVELOPMENT

The discovery well, Lakeview No. 1, section 25, generally known as the Lakeview Gusher, was spudded by the Lakeview Oil Company on January 1, 1909. At a depth of 1655 ft, the well was acquired by the Union Oil Company through purchase of the controlling stock of the Lakeview Oil Company. Drilling was then continued to 2225 ft where the Lakeview sand was encountered.[1] The well blew in on March

FIG. 1 — REGIONAL MAP OF THE TAFT-MARICOPA AREA

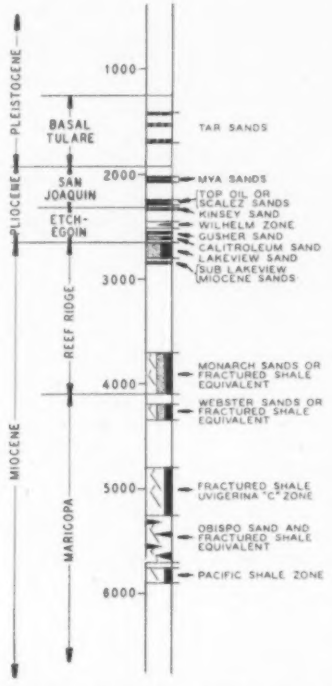

FIG. 2 — COLUMNAR SECTION THIRTY-FIVE ANTICLINE

15, 1910, and flowed uncontrolled for 544 days until September 9, 1911, at which time it died, apparently due to bottom hole caving. It was estimated that at its peak blow, the Lakeview Gusher produced in excess of 68,000 bbl of oil per day, and it was conservatively estimated that the total production approximated eight and one-quarter million barrels. At that time existing storage and shipping facilities in the Midway-Maricopa area were entirely inadequate to handle this uncontrolled production. As a result, twenty sumps or earthen reservoirs were built, covering an area of sixty acres and having a capacity of approximately seven million barrels. Remnants of the levees can be seen today, the largest of which is located approximately one and one-half miles from the well location. It was reported that the oil produced during the uncontrolled flow had a temperature of 92°F and tested 21.2° Baumé gravity at 60°F. The gravity dropped to 18.5° Bé after standing in open reservoirs for seven days and to 17.5° Bé after standing for one year. Based upon subsequent gravity determinations, it appears that the accuracy of the above gravities is questionable. In addition to possibly two hundred and fifty thousand barrels which disappeared through cracks in five of the earthen reservoirs, the loss of approximately three and one-half million barrels of oil is attributed to evaporation and seepage.[3] Subsequent to the blowout, this well was redrilled and deepened five times without establishing satisfactory production.

The development of the Lakeview Pool can be broken into three periods. The first, from the discovery of Lakeview No. 1 in March, 1910, through December, 1934, saw the drilling of seven additional wells. Four of these wells were grouped in sections 33 and 26 while the remaining three were in the immediate vicinity of the discovery well. During the intervening years, it was thought that these two groups were producing from separate horizons.[5] The productive characteristics of these seven wells were sufficiently dissimilar to those of the discovery well that it was not realized the wells were all producing from the same reservoir. After cessation of the gusher, none of the wells completed exclusively in the Lakeview sand were capable of flowing. The sec-

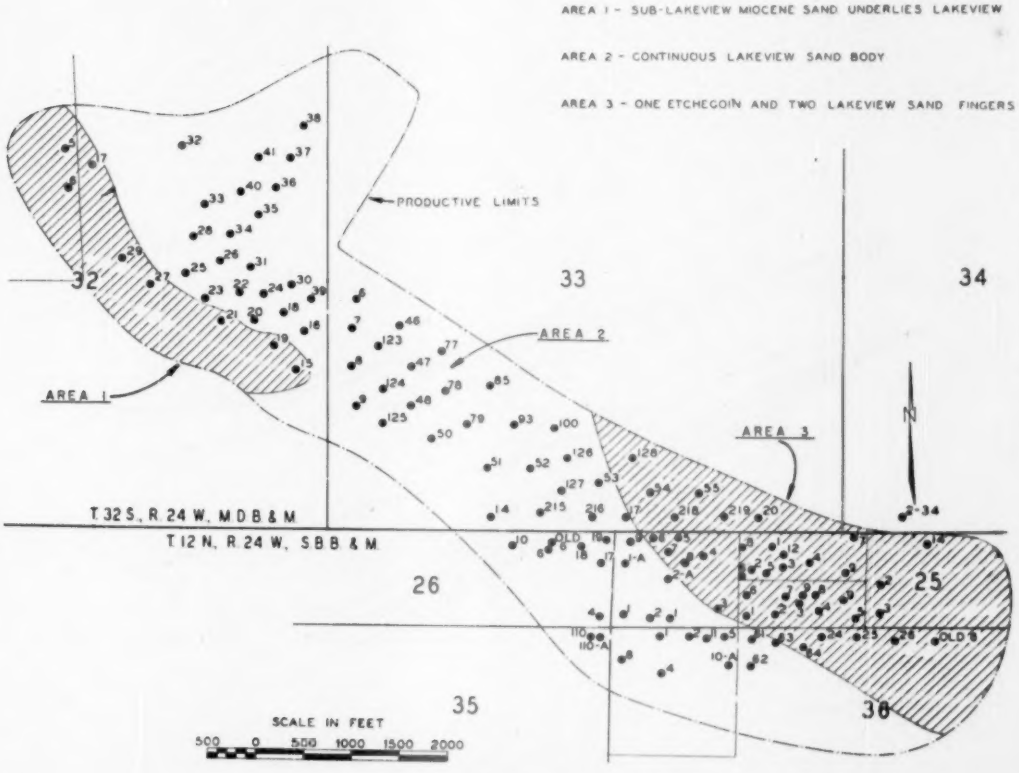

FIG. 3 — AREAS OF DEPOSITIONAL VARIATION

ond period was initiated in January, 1935, by the drilling of the rediscovery well, Hallmark 1-A, section 25. A period of intensive development continued through December, 1940, during which time nearly all the existing wells were drilled. During the third period, from January, 1941, to the present date, five additional wells were drilled in an attempt to more accurately establish the downstructure limits of production. This unusual development history is graphically depicted in Fig. 6. In all, 121 wells were drilled to the Lakeview sand by April 30, 1949, and, of these, 112 were productive.

Operators involved in the development of the Lakeview Pool were the Alford Oil Co., General Petroleum Corp., Hallmark Oil Co., Lakeview Oil Co., Maricopa 36 Oil Co., Merritt-Annex Oil Co., Petroleum Drilling and Exploration Co., Richfield Oil Corp., Sage Oil Co., Standard Oil Co. of California, The Sunset Monarch Oil Co., The Interstate Oil Corp., The Pacific Oil Co., The Texas Co., The United Oil Co., and Union Oil Co. of California.

DRILLING AND COMPLETION PRACTICES

The long development period and the many different companies involved in developing the Lakeview Pool have resulted in a wide variation in drilling practices and completion methods. Most of the wells in the pool were drilled with rotary equipment, but a few were drilled with cable tools. A number of the Lakeview wells were originally shallower zone wells, which were deepened to the Lakeview sands.

It has been the recent practice of some companies to drill to the top of the sand, where the water string was cemented and a water shut-off obtained. A reduced hole was then drilled through the Lakeview zone, the hole underreamed and a slotted liner hung. Other companies favored drilling to total depth before cementing the water string. After obtaining a water shut-off, the cement was drilled out, the hole underreamed and a slotted liner hung.

The time required to drill Lakeview wells has varied from 7 to 91 days. Water string sizes vary somewhat but

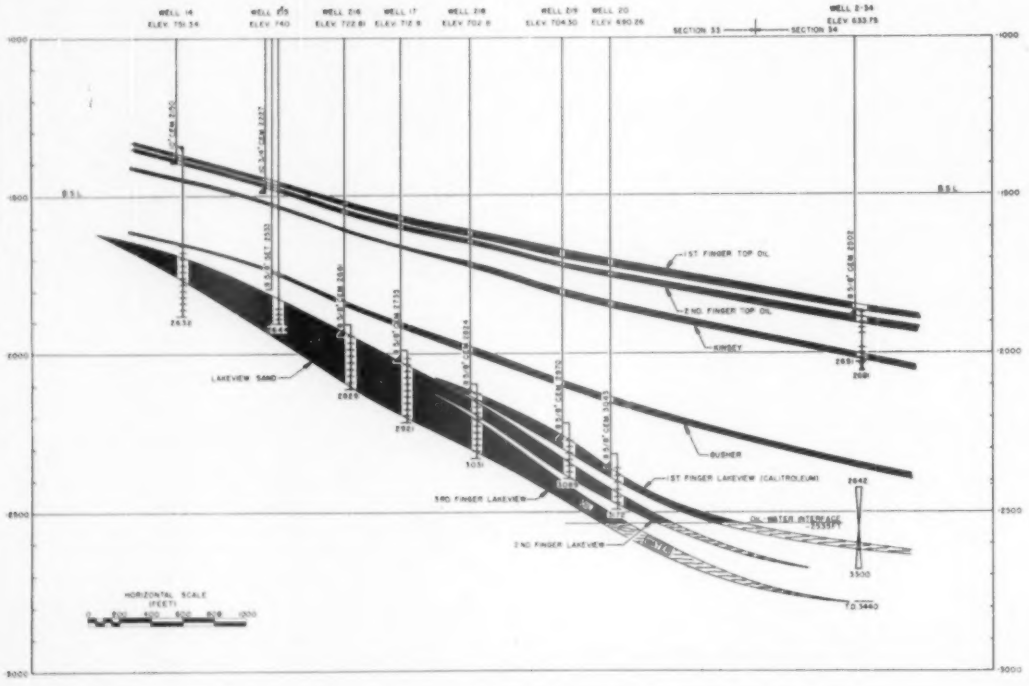

FIG. 4 — WEST-EAST CROSS SECTION NEAR CENTER OF THE LAKEVIEW POOL

are predominantly 8⅝ in. casing. Liners range in size from about 4¾ in. to 7 in. and perforations vary from 60 mesh to 250 mesh.

The majority of the wells were drilled with water base mud, though some of the more recent completions have been with oil or oil base mud.

WELL SPACING

The well spacing in the Lakeview Pool is extremely irregular, varying from about one to seven acres per well. Within this density range there appears to be no correlation between well spacing and cumulative production, even for wells at comparable structural elevations. It is probable that the effect of variable well spacing is obscured by the influence of other factors which, in this pool, have a more pronounced bearing on production. These factors include the number of producing days per month, the downdip rate of gravity drainage, size and efficiency of producing equipment, degree of sand trouble, and extent of sand penetration.

SAND CHARACTERISTICS

The Lakeview sands vary considerably in their characteristics both vertically and laterally over the extent of the field. Core descriptions indicate that the producing medium varies from compact, poorly sorted, tight, silty, poorly saturated oil sand to loose, friable, well sorted, permeable, well saturated oil sand, with the latter predominating. The presence of streaks of kaolin and limestone is common.

Although the sand grains vary in size from very fine to very coarse, medium to coarse grains predominate. Screen analyses of several core samples show a varation from 0.0190 in. to 0.0355 in. at the ten percentile cumulative point on the screen analysis curve.

Core analysis information on the Lakeview sand is meager. Obtaining core data which is representative is difficult due to poor core recovery and to the inability to satisfactorily measure the characteristics of some of the friable, unconsolidated samples. Though few in number, the samples analyzed appear to cover the range of sand characteristics encountered.

Table I is a recapitulation of the available core data. Included are analyses on four laboratory compacted samples which gave data that appear rea-

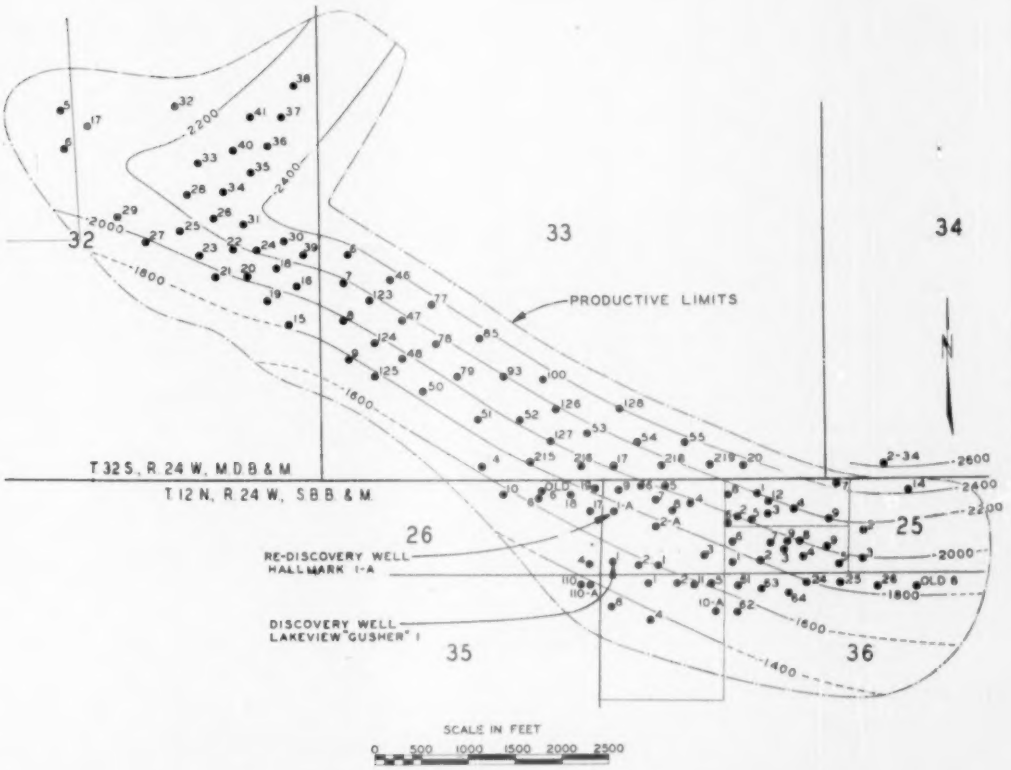

FIG. 5 — SUBSURFACE STRUCTURE MAP — CONTOURS ON TOP OF LAKEVIEW SAND

sonable. These data were included on the basis that a considerable portion of the Lakeview sand is loose and unconsolidated. Incorporation of these analyses on laboratory compacted samples is a conservative measure since it results in larger estimates of the tank oil originally in place and smaller estimates of recovery percentages.

Tests on 11 samples indicated that permeabilities to formation water are about 80 per cent as large as air permeabilities, while permeabilities to fresh water are only about 46 per cent as great as air permeabilities.

FLUID CHARACTERISTICS

The oil obtained from the Lakeview Pool is a naphthenic type crude averaging about 22.5° API gravity. Both initial pool pressures and original saturation conditions in the pool are unknown. Therefore, it has been assumed

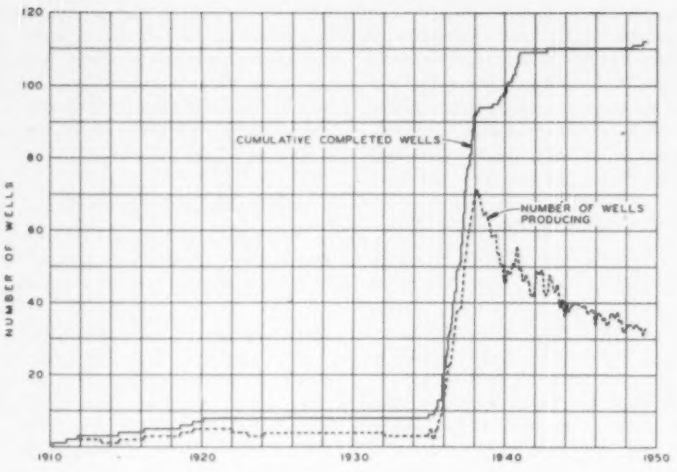

FIG. 6 — NUMBER OF PRODUCING WELLS

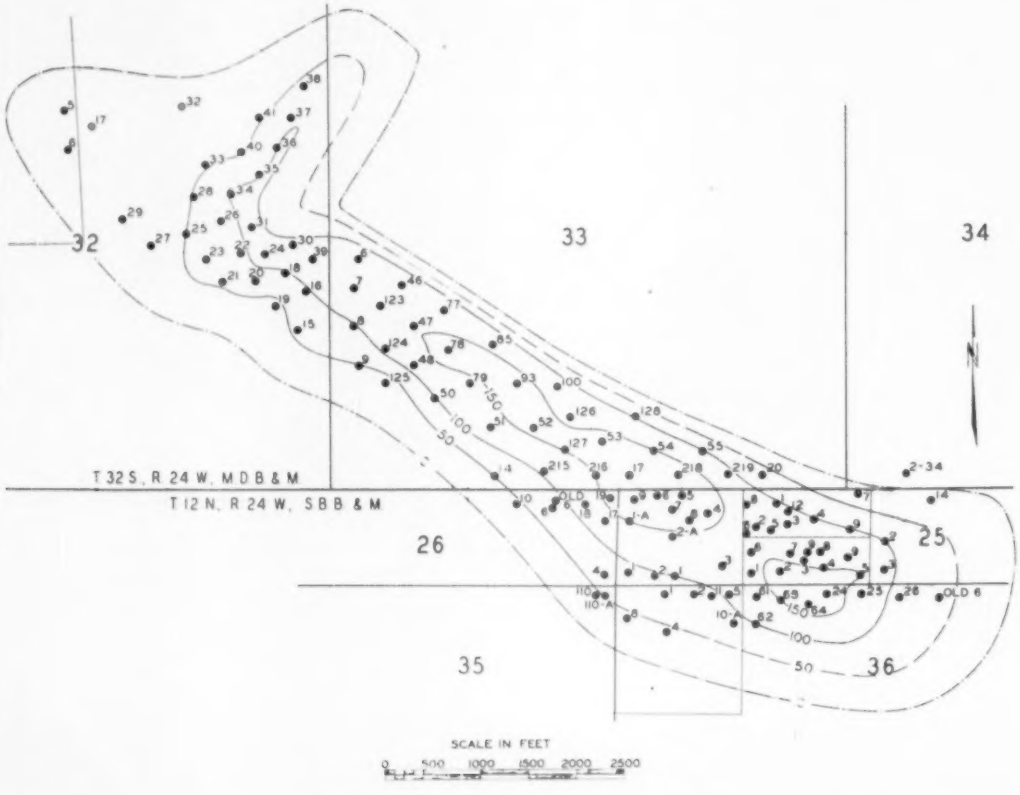

FIG. 7 — ISOPACHOUS MAP, NET PRODUCTIVE LAKEVIEW SAND

that initially the pool was saturated and had no free gas cap. It has also been assumed that the initial pressure was equal to a hydrostatic column of salt water equal in height to the average depth of the pool. In most California oil fields, original reservoir pressures can be approximated in this manner.[4] Neither subsurface nor recombined samples of Lakeview hydrocarbon have been analyzed, so it is necessary to rely upon generalized pressure-volume-temperature data for estimates of fluid behavior at reservoir conditions. Using these assumptions and for an average pool depth of 2875 ft the initial pressure would be about 1300 psia, the initial solution gas-oil ratio about 200 cu ft per bbl and the initial formation volume factor about 1.106 bbl of reservoir space per barrel of tank oil.[5,6]

Table I — Lakeview Sand Characteristics

Porosity, Per Cent of Bulk Volume

No. of Samples	Porosity Range, Per Cent	No. of Samples Laboratory Compacted
3	40.0 to 41.6	2
7	35.0 to 39.9	2
15	30.0 to 34.9	0
6	25.0 to 29.9	0
1	24.0 to 24.9	0
Total 32	Average 33.1 Per Cent	Total 4

Air Permeability, Millidarcys

No. of Samples	Permeability Range, md	No. of Samples Laboratory Compacted
3	10,000 to 10,500	2
4	5,000 to 9,999	0
12	1,000 to 4,999	2
5	495 to 999	0
Total 24	Average 3655 md	Total 4

Capillary Pressure Interstitial Water Saturation, Per Cent of Porosity

Interstitial Water corresponding to Permeability of 3655 md equals 23.5 per cent

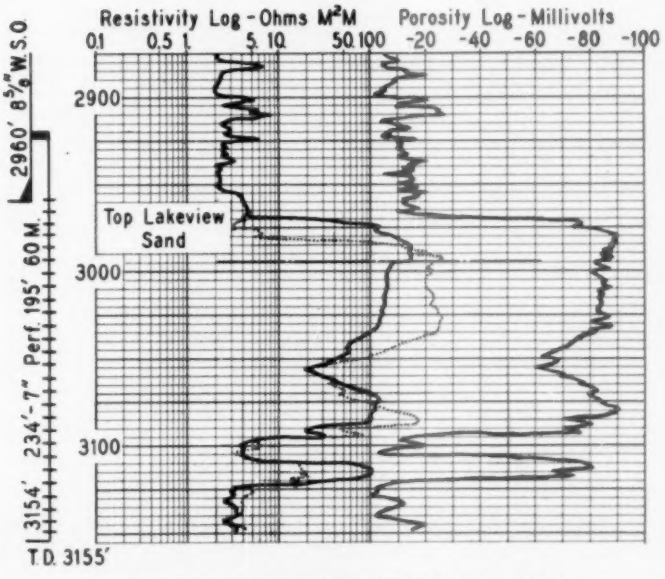

FIG. 8 — TYPICAL ELECTRIC WELL LOG AND COMPLETION METHOD

TANK OIL IN PLACE

In view of the inactivity of the edgewater, it has been assumed that the net productive reservoir volume in 1935 was identical to the productive volume at the time of the pool's discovery. The reservoir volume was determined by the volumetric-porosity method from an isopachous map contoured on 10 ft sand thickness. A similar isopachous map contoured on 50 ft sand thickness is shown on Fig. 7. The sand count was based upon a consideration of core data and electric logs. Of the 121 wells which penetrated the Lakeview sand, 85 were wholly or partially cored, while 92 have electric logs. A typical electric log of the Lakeview zone is shown on Fig. 8. The sand pinchouts upstructure and along strike were determined from cross-sectional analysis by assuming that the sand continued to thin uniformly beyond points of control. The lower limits of production were established by determining the oil-water contact on the basis of sands which were wet at the time of drilling.

The net productive sand volume was calculated to be 41,798 acre-ft. The productive sand encompasses an area of 588 acres and has an average thickness of 71 ft. Fig. 9 shows the approximate structural distribution of the net productive sand volume as determined by superimposing the isopachous map upon the structure map and computing the sand volume between structure contours.[7]

The tank oil originally in place was calculated to be 74,240,276 bbl, using the core data of Table I and a formation volume factor of 1.106 bbl of reservoir space per barrel of tank oil.

RESERVOIR PERFORMANCE

The production history of the pool is shown graphically in Fig. 6 and 10. As of April 30, 1949, the average pool production rate was about 2000 B/D.

At that time a total of 33 wells were still producing.

It is significant to point out that about 20 per cent of the cumulative oil production was estimated. However, it is believed that the estimates were conservative. The estimates were made principally on oil produced during the interval of 1910 to 1917, and about 90 per cent of the estimate was for oil presumably produced by the "Lakeview Gusher". For those wells where Sub-Lakeview Miocene or Gusher production was commingled with Lakeview production, a reasonable amount was deducted in an effort to obtain only Lakeview production.

Accurate water production statistics are not available for certain relatively small properties within the pool. However, the water production accumulated for those properties on which it was reported has been used in determining the water cut shown on Fig. 10. Accurate gas production data are not available for the pool and have, therefore, not been included.

In the Lakeview Pool, it has been the practice to utilize static fluid level data, in place of bottom hole pressures as a basis for studying reservoir behavior. Depth pressure data are so meager, consisting of only nine surveys taken during 1937, as to be inadequate for purposes of reservoir analysis. Fluid level determinations suggest that the fluid surface is not level, but tends to slope downdip with the structure. Because sufficient data are not available for the preparation of iso-fluid level maps, arithmetically averaged fluid levels have been used. The excellent agreement between these averaged fluid levels and fluid levels determined from well performance is shown on Fig. 11. Curve A represents the average of actual fluid level measurements while Curve B designates time-depth depletion fluid levels. The latter was determined by plotting the subsea depth of the bottom of the well, providing it is not deeper than the base of the sand, versus the date that the well ceased to produce from lack of fluid.

The principal production problem experienced in Lakeview zone wells has been sand trouble. Prior to 1936, most wells were completed with liners having wide slots generally ranging from 120 to 250 mesh. Excessive sand difficulties, which necessitated frequent bailing, perforation cleaning and equipment repair and replacement, resulted from these completions. The extent of the sand difficulties prompted some of the operators to conduct experiments on the bridging characteristics of the sands, which in turn resulted in a trend towards gravel packed liners of the circulated type and towards conventional liners with 60 mesh slots. Although the effects of these changes in completion technique have not been studied in detail, it appears that they have been instrumental in practically eliminating sand trouble.

The Lakeview Pool is apparently bordered on its downstructure side by a comparatively inactive edgewater. However, as shown on Fig. 12, there are three general areas in the pool that have produced appreciable quantities of water. Areas 1 and 2 are regions in which edgewater has been coned into wells. These areas generally exist along competitive property lines. In Area 1, the first significant appearance of water

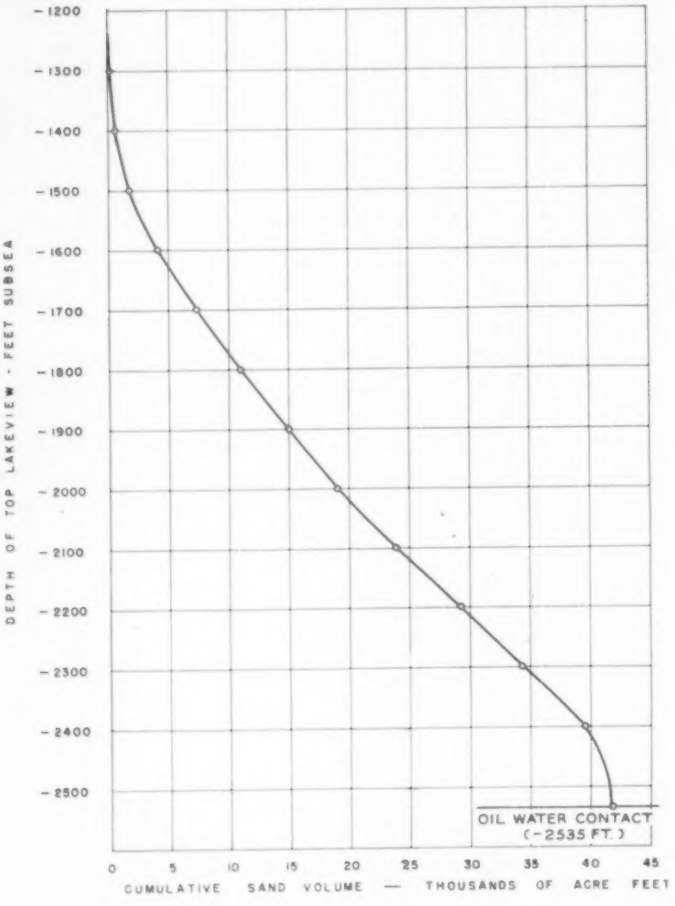

FIG. 9 — STRUCTURAL DISTRIBUTION OF SAND VOLUME

occurred in 1940 during a period of relatively high production which followed the completion of the majority of the wells. An inspection of fluid levels disclosed that the wells affected by water were surrounded by a pressure sink, which probably encouraged the movement of water into that region. During a period of reduced production in 1941, the water produced in this area declined noticeably. Concurrent with the increase in production during 1942, water again entered the area. Generally since about 1944, decreased gross production rates have resulted in gradually diminishing water cuts. Area 2 is characterized by initially clean wells which, after a period of approximately three months of intensive production, showed rapidly increasing water cuts. After 1937, following a decline in production rates, water receded from the area, only to reappear again during the period of heavy production which began in 1942. The water behavior thereafter has responded similarly to that in Area 1. Area 3 is a region which apparently has been invaded by water from other zones. A review of the mechanical conditions of wells which penetrated the Lakeview sand high on the structure suggests that any of several wells could have introduced foreign water into the Lakeview sand through unplugged sidetracked casing or from incompletely plugged sands. In addition, it appears that the low pressure Lakeview zone was readily susceptible to an invasion of foreign water. The belief that these structurally high wells were affected by a foreign water is further substantiated by the fact that wells highest on the structure produced water before the lower structure wells. Analyses of water produced by wells in Area 3 shows that water from the higher structure wells contained slightly smaller concentrations of salt than those further downstructure. Water produced from these downstructure wells in Area 3 was similar to Lakeview edgewater. It is conceivable, however, for a foreign water, in percolating through the Lakeview sand, to dissolve small quantities of salts so as to become similar to Lakeview water. The invasion in this area has not been serious since total water production seldom exceeded 200 bbl per day. There is no evidence that oil production was obstructed by this invasion. The ingression of alien water has been curbed to the point where it is now negligible.

Reservoir characteristics which are highly favorable to gravity drainage, make this pool particularly susceptible to effective gravity drive. The absence of active water drive and the depletion of gas by the "Lakeview Gusher" made gravity drive the dominant reservoir agent.

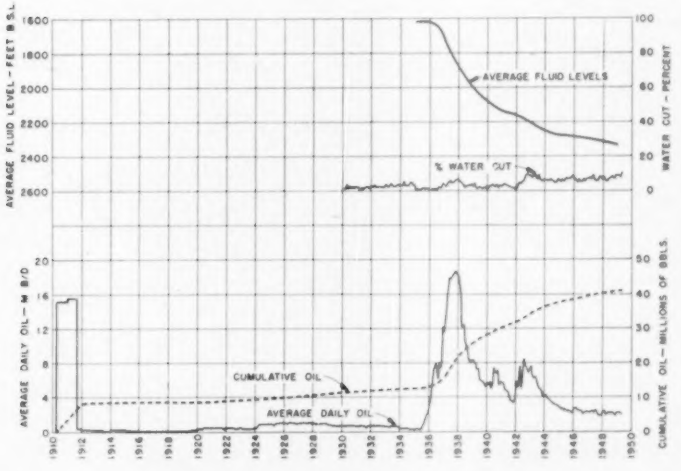

FIG. 10 — PRODUCTION HISTORY — LAKEVIEW POOL

The production decline characteristics of individual wells are dependent upon their structural location. Wells high on the structure exhibit rapid declines in production rate until they go dry. Wells lower on the structure produce for a substantial period of time at a relatively constant rate before their production declines rapidly due to the recession of the fluid level downstructure past the wells.

A comparison between the daily average production rate and fluid level decline represented by Fig. 10 shows that the decline in fluid level is intimately dependent upon the withdrawal rate. This relationship between withdrawals and fluid level is more strikingly illustrated on Fig. 13, which shows the fluid level versus the cumulative oil production. The straight line relationship between the fluid level and the cumulative oil production from January, 1942, to January, 1949, indicates that during that period the oil recovery has been essentially constant at about 53,000 bbl for each foot drop in fluid level. Such a relationship provides a simple means of estimating reserves, provided the lowest depth of drainage can be accurately determined. This method does not allow for thinning of the sands as the oil-water contact is approached.

The "Lakeview Gusher" was probably accompanied by an unstable localized reduction in pressure, which resulted in a release of the bulk of the original solution gas in the region affected. Following cessation of the "Gusher's" uncontrolled flow, a period of establishing equilibrium took place. During this period a low pressure free gas cap of small areal extent was apparently created. This was evidenced by later drilling. The establishment of equilibrium resulted from a movement of oil into the drained region and an equalization of pressures throughout the reservoir. The movement of fluid into the depleted area is substantiated by rising fluid levels and increased production in Wells No. 215, section 33, and No. 6, section 26, from 1921 through 1927. These data indicate the period to establish equilibrium was in excess of 16 years.

By relating the average fluid level at any particular time to the structural distribution of the sand volume, the

number of acre feet drained at that time may be approximated. It is recognized that drainage is not complete above the fluid level and that the recovery is a function of time, but it is assumed that additional economic recovery from that region will be negligible. An analysis of Fig. 14, which associates the drained cumulative reservoir volume with cumulative production of oil, shows the ratio to approximate that of a straight line. This relationship indicates that such functions as formation volume factor, edgewater encroachment, water production, gas production, porosity, and interstitial water remain approximately constant over the period beginning with the rediscovery of the pool in 1935 through the present date. Of particular interest is a straight line extension of this curve

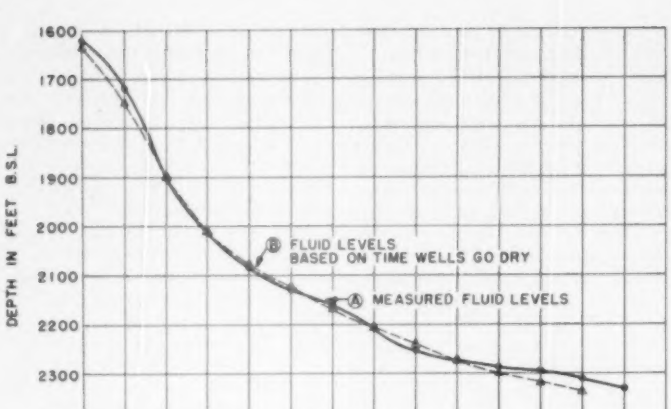

FIG. 11 — COMPARISON OF MEASURED FLUID LEVEL WITH TIME-DEPTH DEPLETION FLUID LEVEL

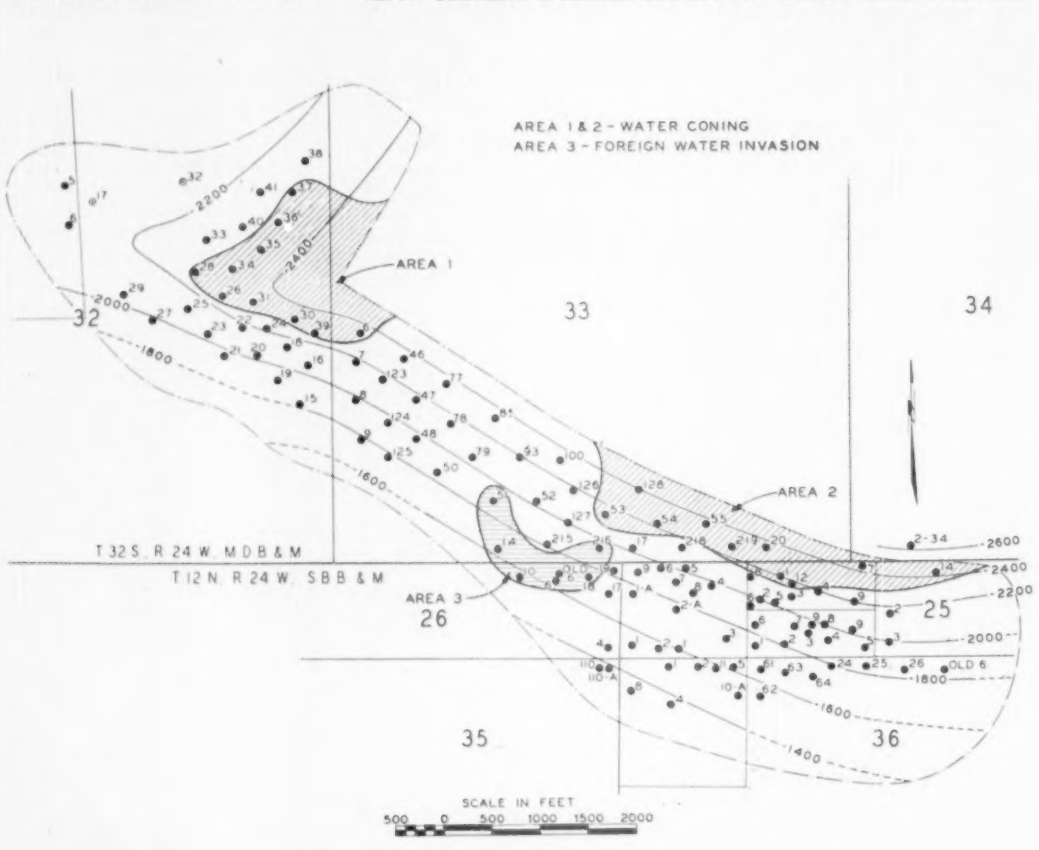

FIG. 12 — AREAS OF WATER CONING AND FOREIGN WATER INVASION

to represent a point of zero drainage. The first impression is that approximately 9,000,000 bbl of oil were produced without accompanying reservoir space being vacated. In the absence of edgewater encroachment, this apparent discrepancy must be related to the difference in physical properties of the fluid as it existed before and after the period of uncontrolled flow. Lewis[9] states that when original pressures are reduced, gas will come out of solution and expand. Some oil will be driven from the pores by the free gas and partial saturation conditions will be developed corresponding to the insular regions in a capillary system induced by gravity drainage. In the insular region, small globules of gas, separate and distinct from one another, are interspersed in the oil. In this stage the sand has no gas permeability, the gas is entrained in the oil and probably will move in the oil stream. In effect, single phase flow would still exist in the sand and the freed gas would merely reduce density and impart greater elasticity to the remaining liquid. The foregoing statements appear to be particularly applicable to the Lakeview Pool. It is believed that after the period of uncontrolled flow and during the period in which equilibrium was being re-established an accumulation of free gas in the insular region did occur and as a result of the imparted pseudo elasticity of the liquid the reservoir was essentially refilled with a fluid differing radically from the original fluid. The apparent production discrepancy of 9,000,000 bbl of oil as shown in Fig. 14 can be attributed to the refilling of the reservoir due to the accumulation of insular free gas.

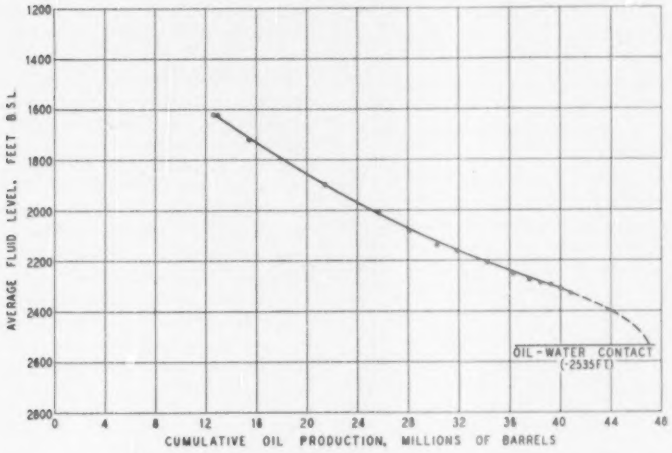

FIG. 13 — CUMULATIVE OIL PRODUCTION VERSUS FLUID LEVEL DECLINE

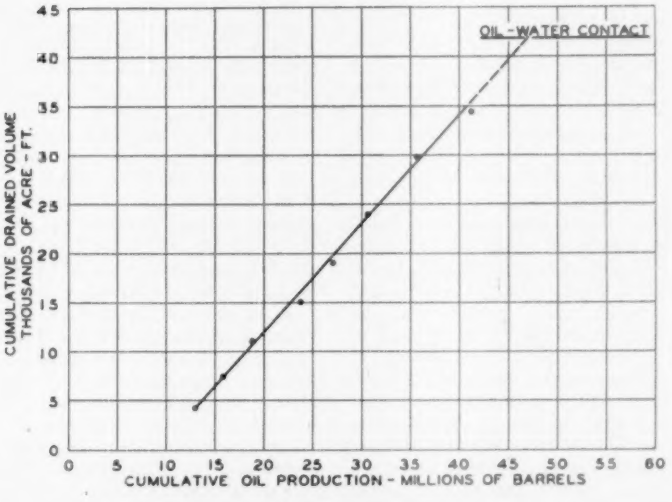

FIG. 14 — RESERVOIR DRAINAGE — PODUCTION RELATIONSHIP

An extrapolation of the curve of Fig. 14 to the oil-water contact gives an indication of the ultimate recovery attainable. It is not inferred that this recovery will be reached since neither the feasibility nor economies of draining the pool to the oil-water contact have been investigated.

Table II gives a resumé of estimated oil originally in place, recoveries as of May 1, 1949, and estimated ultimate recoveries assuming that the pool is drained down to the oil-water contact.

Table II — Oil Recovery

Tank oil originally in place, barrels	74,240,276
Barrels per acre foot originally in place	1,776
Tank oil produced to May 1, 1949, barrels	41,082,498
Barrels per acre-ft produced to May 1, 1949	983
Per cent recovery as of May 1, 1949	55.3
Estimated ultimate oil recovery, barrels	47,000,000
Estimated ultimate recovery in barrels per acre ft	1,124
Per cent ultimate recovery	63.3

CONCLUSIONS

The performance of the Lakeview Pool demonstrates the effectiveness of gravity drainage as a reservoir mechanism. In the absence of active edgewater and/or appreciable gas drive, gravity is the principal reservoir con-

trol. The pronounced dip and the favorable sand and fluid characteristics make gravity drive particularly effective. The recovery to date has been about 55.3 per cent of the tank oil originally in place, and it is estimated that an ultimate recovery of 63.3 per cent is attainable.

The greater portion of the pool's water production has been due to coning the inactive edgewater into low structure wells located along competitive property lines.

ACKNOWLEDGMENTS

Grateful acknowledgment is hereby made to the management of the Standard Oil Co. of California for permission to publish this paper, and to Miss L. R. Kirwan and N. R. Powley II for their assistance in assembling the data.

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DISCUSSION

By C. F. Gates, General Petroleum Corp., Los Angeles, Calif.

Sims and Frailing are to be commended for analyzing and summarizing the history of a pool which amply demonstrates how important gravity drainage can be as a recovery mechanism under favorable conditions. This pool is unique in having first a period of production in which the depletion mechanism dominated the recovery and then another distinct period in which recovery was almost exclusively by gravity drainage. Fluid level data shortly after the beginning of the second period of development, January, 1936, indicated an average pressure of about 185 psi or 14 per cent of the estimated initial pressure of 1300 psi. In order to visualize these relative values, one needs to examine Fig. 13 keeping in mind that the initial pressure was the equivalent of a fluid level about 1200 ft above sea level. Recovery to January, 1936, was 12.5 million bbl, or 17 per cent of the original oil in place. Assuming several wells and more uniform withdrawals, recovery by the depletion mechanism alone would probably have been about 20 per cent compared with 63 per cent estimated total for both depletion and gravity drainage.

It is of some interest to speculate about what the recovery might have been if no blowout had occurred and all produced gas had been returned to the top of the structure permitting gravity drainage to take place at higher pressure. Under present conditions about 37 per cent of the initial oil in place will remain in the reservoir. If the remaining oil saturation were the same at high pressure as at low pressure, then additional oil would be recovered because of the difference in formation volume factor of the residual oil. As an upper limit only 10 per cent of the residual oil would be recovered by this means. The total recovery would then be more than 63.3 per cent, but less than 67 per cent of the original oil in place.

DISCUSSION

By Vaughn S. Moyer

The Lakeview pool, in its latter production history, at least, is as fine an example of gravity drainage performance as can be found in California. Fortunately for the reservoir engineer, the drive appears to be uncomplicated by water or internal energy forces, permitting some more or less unencumbered calculations to be made for gravity drainage. Since a great many California pools react unpredictably — insofar as theoretical behavior is concerned—such calculations should enhance the knowledge of gravity drainage considerably. It is true, of course, that an isolated case such as this cannot of itself become the gauge whereby all gravity behavior is judged, but nevertheless it can serve as a guide to the trend to be expected.

Perhaps the authors have made such calculations. If so, a few words from them on the subject would be well worthwhile. It would be interesting to know if the observed gravity drainage deviates materially from the calculable values, and if so, in which direction—lesser or greater?

Author's Reply to Vaughn S. Moyer:

The successful application of theoretical gravity drainage equations to the Lakeview Pool is unfortunately hindered by the meager data available concerning sand and fluid characteristics. However, using the range of data that may be applicable, Darcy's equation for maximum downdip flow of oil" gives oil rates for 1938 in the order of 14,000 to 18,000 B/D. When this is compared to peak production rates of about 18,000 B/D in 1938, it appears that good agreement is indicated. Similar calculations for 1949 indicate maximum downdip oil movement in the range of 7,000 to 9,000 B/D. When compared with the present oil production rate of about 2,000 B/D, this may indicate that sufficient wells are not available to produce the pool to the maximum rate. Other factors that could contribute to this reduced rate include incomplete sand penetration and reduced effective oil permeability. ★ ★ ★

SOME PRELIMINARY INVESTIGATIONS OF QUANTITATIVE INTERPRETATIONS OF RADIOACTIVITY LOGS

ROBERT E. BUSH, LANE-WELLS CO., HOUSTON, TEXAS, AND **E. S. MARDOCK,** MEMBER AIME,

WELL SURVEYS, INC., TULSA, OKLAHOMA

ABSTRACT

The objective of this paper is to present practical methods of applying radioactivity logs to problems of interest both to those engaged in evaluating fundamental reservoir data as well as to those engaged in subsurface structural work. The basic theories underlying the operation of radioactivity logging methods are briefly discussed along with some of the problems arising in the interpretation of the log. Relative methods of quantitative interpretation are described, with a discussion of relative reference lines and specific examples are given showing the application of these relative quantitative interpretation methods. To show the variation of the methods described, specimen wells penetrating formations widely divergent in point of geologic age were selected to demonstrate the application. A relative reference line is determined for the Neutron Curve and by comparison to known petrophysical data such as porosities from diamond cores, a direct quantitative relationship is developed. The application of this relative calibration curve to logs of unknown wells will permit a reasonably accurate determination of porosity in limestone and dolomite formations. Specific examples are given showing the application of these relative methods of interpretation to logs of the Smackover limestone in Louisiana, the Edwards limestone and dolomites of South Texas, and Permian dolomites of West Texas.

[1] References are given at end of paper.

Manuscript received at the office of the Petroleum Branch October 4, 1949. Paper presented at the Petroleum Branch meeting in San Antonio, October 5-7, 1949, and at the Petroleum Branch meeting in Los Angeles, October 20-21, 1949.

INTRODUCTION

Radioactivity logs have been used extensively by the petroleum industry for a number of years and recognition of their value has grown steadily, not only as tools to aid in the solution of specific stratigraphic problems, but also as potential sources of the basic data necessary for the estimation of net pay and reserves. The value of radioactivity logs for stratigraphic work has been pointed out in the literature,[1,2,4,5,6] and now has long been recognized by the industry, but the quantitative application of the logs has advanced but little beyond the stage of a strong conviction that radioactivity logging curves will some day provide the information on such important quantities as the porosity and the liquid saturation of the formations.

During the past few years the staffs of the Lane-Wells Company and Well Surveys, Incorporated, have devoted a great deal of time, thought, and experimentation to the relationships existing between radioactivity curves and the lithologic conditions encountered, and this paper is, in a manner of speaking, intended as a progress report of this work and includes suggestions which the authors have found useful in the interpretation of radioactivity logs.

The section on theory is not intended as a complete exposition of the physical processes involved, but rather as a brief introduction to the reader of these processes so that he may acquire a better understanding of the behavior of the radioactivity curves under the varied conditions encountered in normal well logging.

Three relative methods for using neutron logs for the quantitative estimation of porosity in limestone or dolomite are presented. These methods are based on the comparison of logs and porosity data from wells in Louisiana, South Texas, West Texas, and New Mexico.

These areas were selected because not only were there more core data available from these areas but also the majority of these data were from limestone or dolomitic zones. The correlation between core data and logs is simpler for limestones and dolomites than it is for sandstones due to the fact that sandstones are more complex than limestones and differ more widely among themselves as to composition of cementing materials, siltiness, etc. When data applicable to the various types of sandstones are available, the authors hope to present a discussion similar to this paper covering sandstones or possibly a more general discussion covering all types of reservoir rocks.

The relative methods for estimating porosity which are presented in this paper fall short of the absolute method sought. However, these methods possess the advantage that they can be applied to almost any neutron log as long as the range of application is held within the limits imposed by the local lithologic conditions which prevailed during calibration, i.e., these methods are for short range application only.

THE THEORETICAL BASIS FOR RADIOACTIVITY LOGGING

The two radioactivity logging curves commercially available today are the

Gamma Ray Curve and the Neutron Curve. Each of these curves consists essentially of relative measurements of primary and/or secondary gamma ray intensities recorded as functions of depth.

The Gamma Ray Curve is obtained by lowering into the well a detector of gamma rays (Fig. 1-B) which is connected to surface recording equipment and the intensity of the gamma rays emitted naturally by the rock strata are recorded beside the proper depth marker, while the chamber is being raised to the surface.

The neutron survey is obtained with a short ionization chamber, to which there is attached a capsule containing a radium-beryllium mixture which serves as the source of neutrons, (Fig. 1-A). The ionization chamber of this instrument is affected by the gamma radiation resulting from the bombardment of the formation by neutrons and by the primary gamma radiation from the sources which is scattered by the formation whereby some of it is directed toward the ionization chamber. The natural radiation from the formations also affects the chamber, but the intensity of this radiation is very small compared to that of the gamma radiation from the other causes enumerated above.

Response of Curves to Various Conditions

Fig. 2 is a chart showing the response of the radioactivity logging curves for different lithologic conditions, and Fig. 3 shows the effect of hole size and casing.[4,5,6] These charts will not be discussed at this time but they will be discussed later in the text in connection with the description of the physical processes involved.

The Natural Gamma Ray Curve

The response of the natural gamma ray curve is clearly explained on the relatively simple basis that some rocks radiate more gamma rays than others, and Russell[3] has shown that there is a strong correlation between a rock classification and the intensity of the gamma radiation emitted by the members of the class (Fig. 4).

The Neutron Curve

The mechanism of response of the Neutron Curve is more complex than that of the Gamma Ray Curve, however, and in order to understand its behavior it will be necessary to discuss some of the basic factors affecting its operation.

Components of the Neutron Curve

The total gamma radiation reaching the ionization chamber of the neutron logging instrument while it is making a log has three main sources of origin, as follows:

I (total gamma radiation $= I_1 + I_2 + I_3$

Where:

I_1 is the intensity of the gamma rays induced by the action of neutrons upon the formation.

I_2 is the intensity of the scattered radiation, i.e., the gamma radiation which was originally emitted by the source capsule and which has been scattered by the formation.

I_3 is the intensity of the gamma radiation emitted by the formation rocks themselves.

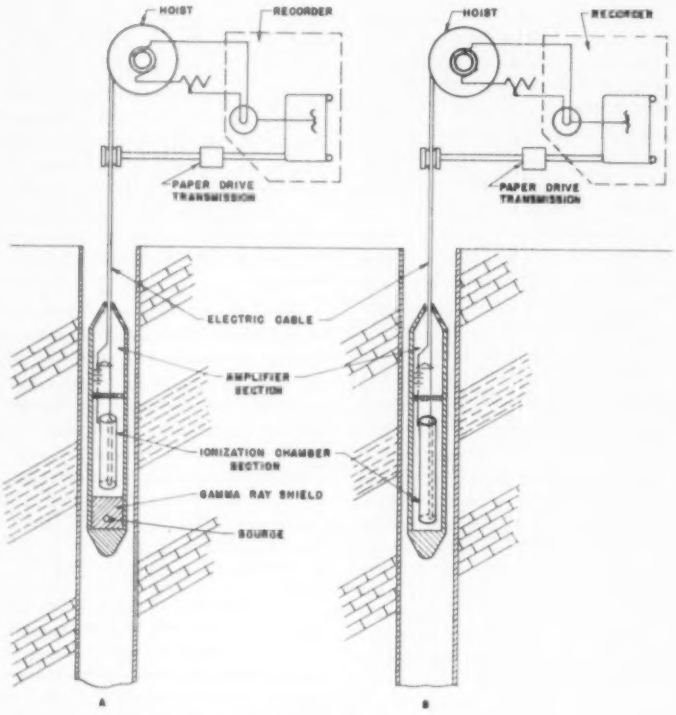
The Neutron Induced Gamma Radiation Component (I_1)

The intensity of the gamma rays reaching a cavity in the rock from a point source distance r away would be[1]

$$I_r = \frac{SQCe^{-\mu_1 r}}{r^2}$$

Where:

S is the source strength, a constant, characteristic for example, of the alpha



A COMPONENTS OF NEUTRON LOGGING EQUIPMENT
B COMPONENTS OF GAMMA RAY LOGGING EQUIPMENT

FIG. 1 — RADIOACTIVITY LOGGING EQUIPMENT

rayer used with the beryllium in the source capsule.

Q is a factor due to the neutron spectrum of the source flux. Q is a quantity which increases as the energy of the most populous group of neutrons in the source flux becomes larger. Q is constant for a given source.

C is a quantity which corresponds to the average effectiveness with which the elements present in the rock convert the neutron flux into a gamma ray flux. It varies with the chemical composition of the rocks, and it is larger for dry rocks than for wet ones (because, for example, gamma rays resulting from neutron capture are more energetic for most of the earth elements than they are for hydrogen).

μ_1 is the value to which the full absorption coefficient for the neutron flux converges as more rock is penetrated μ_1 is critically influenced by the hydrogen content of the formation; μ_1 increases with the concentration of hydrogen.

r is the distance through the rock from the source to the cavity.

The above reasoning also applies to a geometry which includes a well bore filled with oil or water whose diameter is small compared to the spacing between the source and ionization chamber. For closer spacing a more exact, and therefore more complex, treatment will be required and this is outside the scope of this paper.

For a given source, S and Q are constants and therefore do not affect the character of the well log except that if these constants are too small, the log will contain very high statistical fluctuations. All of the neutron sources used in logging comply very closely with standards which maintain the S and Q factors so that there are only very small deviations from one source to another.

The variable C affects the character of the log in that its main influence is exerted when the chemical composition of the rock changes. Sandstone and limestone, for example, have different C values.

The variable μ_1 is a determinative quantity affecting the I_1 component of the Neutron Curve; and therefore since this is the most important component, it can be said that with only a few exceptions μ_1 is determinative for the Neutron Curve.

The effects due to the influence of hydrogen on C and μ_1 cooperate to decrease the intensity of radiation for increasing hydrogen concentration; and it is for this reason that the neutron curve is a commercial means of studying the hydrogen content in the formations. This also explains the low response of the Neutron Curve opposite liquid filled porous zones, as shown in Fig. 2.

Fig. 5 shows how I_1 varies with porosity in limestone in an exponential manner.

On the other hand the increase in activity observed with anhydrite (Fig. 2) is mainly due to its larger C factor, although μ_1 is small due to the absence of water.

The log responds to shale in the same manner as to a porous zone (Fig. 2) because the C and μ_1 factors for shales are similar to those in porous zones, due to the high concentration of water, the presence of which is rendered less obvious by the fact that it is held in a loose state of chemical combination.

FIG. 2 — GRAPHIC INTERPRETATION OF RADIOACTIVITY LOGS

The Scattered Gamma Ray Component (I_2)

If the same geometry as above is considered but with a gamma ray source substituted for the neutron source, the intensity of the gamma radiation acting on the absorbing material in the rock cavity would be:

$$I = \frac{Pe^{-\mu_2 r}}{r^2}$$

Where:

P is a source constant which determines the source strength.

μ_s is the average coefficient of absorption of the rock formation for the gamma rays emitted from the source. Since μ_s is a function of density, it might be expected that the I_s component would vary inversely with density. The I_s component actually does behave in this manner but this density effect is greatly overshadowed by the effect of borehole diameter.

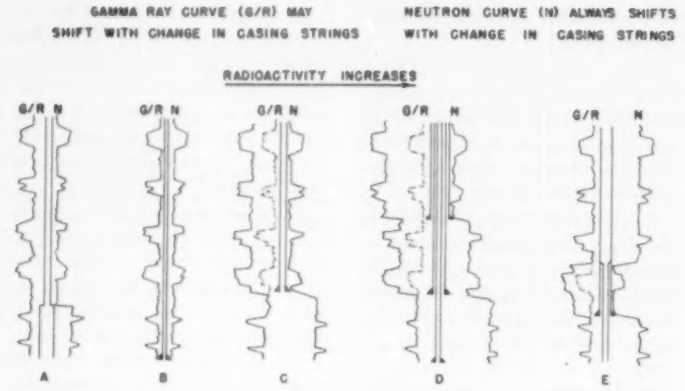
Fig. 6 shows that the I_s component is directly proportional to the borehole diameter, although there is also an influence due to other factors, mainly the rock density.

This preponderance of the borehole diameter effect can be best understood by recalling that all of these scattered gamma rays have undergone losses of energy through the scattering process, so that only the photons which were scattered quite close to the well face are able to penetrate the rock and reach the ionization chamber. Hence, the relatively small effect of density. On the other hand, as the well face moves away from the instrument as it does when an enlarged section of bore-hole is traversed, a larger solid angle of the radiation from the source is subtended by the well face which becomes more thoroughly illuminated by the gamma rays some of which are backwards scattered. The ionization chamber can then "see" more of the scattered radiation. The I_s component is therefore influenced principally by bore hole diameter changes and is responsible for the shift in the curve opposite borehole diameter changes (Fig. 3-A). I_s is also affected strongly by casings and it is largely responsible for the shifts observed opposite casing seats in Fig. 3, (B, C, D and E).

The I_s component is not as strongly effected by the steel casing; however, the cement behind the casing has an attentuating effect on the neutrons, and contributes to the casing shift observed in Fig. 3.

The Natural Gamma Ray Component (I_γ)

While the Neutron Curve always has this component consisting of the gamma



A OPEN HOLE WITH CAVITY. NEUTRON SHIFTS TO LEFT WITH DECREASE IN HOLE SIZE.

B ONE STRING OF CASING. CONTINUOUS UNIFORMITY.

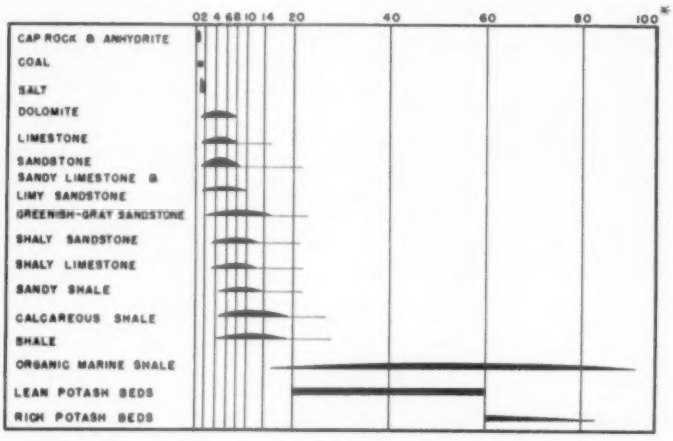
C OPEN HOLE AND CASING. NEUTRON CURVE SHIFTS TO LEFT AT CASING SEAT.

D MULTIPLE CASING. NEUTRON CURVE SHIFTS TO LEFT AT EACH CASING SEAT.

E CASING AND LINER. NEUTRON CURVE SHIFTS TO LEFT AT CASING SEAT AND TO RIGHT AT LINER.

GAMMA RAY CURVE MAY ACT IN SAME MANNER AS NEUTRON CURVE BUT TO A LESSER DEGREE EXCEPT IN "A" WHERE THE GAMMA RAY CURVE REMAINS UNAFFECTED BY THE CHANGE IN HOLE SIZE.

FIG. 3 — EFFECT OF PHYSICAL BOREHOLE CONDITIONS ON GAMMA RAY AND NEUTRON CURVES



FROM W. L. RUSSELL, BUL. OF A.A.P.G., VOL. 25, NO. 9, SEPT. 1941, P1775.

* $\times 10^{12}$ GRAMS RADIUM EQUIVALENT PER GRAM OF ROCK.

FIG. 4 — GAMMA RAY RESPONSE TO SEDIMENTARY ROCKS

radiation emitted by the rock through natural disintegration processes, it will usually be too small to merit consideration in most reservoir rocks.

However, important exceptions to this rule have been noted. Certain bentonitic sands of South Texas, partilly silted sands generally, radioactive limestone, and others elsewhere, exhibit sufficient natural gamma ray activity so that the Neutron Curve is seriously affected.

It is important to note that the Neutron Curve may be corrected for this natural activity by means of the Gamma Ray Curve. This is done by taking into account the relative sensitivities of the two ionization chambers for gamma rays. For any given sensitivity scale the gamma ray instrument will be found to be sixteen times more sensitive than the neutron instrument. For example, opposite a bentonitic sand the Gamma Ray Curve indicated a high intensity of natural gamma radiation by making an 8-inch swing to the right of the normal value for sands. The sensitivity scales were 6 and 10 inches respectively for the gamma ray and neutron curves. In order to calculate the correction to be applied to the Neutron Curve we have:

$\frac{8}{16} \times \frac{10}{6} = .833'' =$ the correction to subtract from the Neutron Curve deflection in order to correct it for the natural gamma radiation.

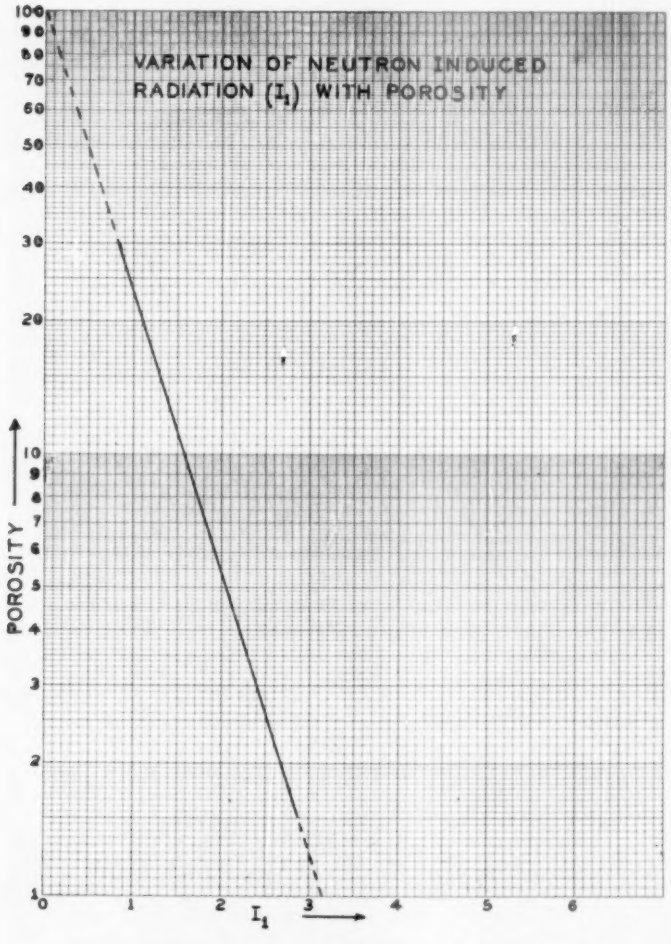


FIG. 5 — EFFECT OF POROSITY ON THE NEUTRON INDUCED RADIATION (I_1)

Relative Importance of the Three Components

The predominating component of the Neutron Curve is I_1. For most cases, where the bore hole diameter is small and does not change appreciably, the I_2 component is very small and exhibits no large variations. The I_3 component is usually small enough to be neglected when the log is used in stratigraphic correlation work; but where a quantitative application is to be attempted, it is sometime found necessary to perform the operation previously outlined and correct the neutron curve for the influence of natural gamma radiation.

Sampling of Radioactivity Logging

In order to understand the quantitative application of radioactivity curves the sampling process involved must be considered. Sampling as the term is used in geological investigations means the description of the manner in which a specific property of the earth is weighted throughout the portion of the earth being studied.

Sampling of the Gamma Ray Curve

Fearon[1] has shown that for gamma ray logging within a cylindrical bore hole, the weighing factor falls off radially as a function of the absorption coefficient of the rays emitted by the radioelement present.

The weight factor may be computed, for a stationary measure and for any particle in the vicinity of the detector by a calculation of the probability of radiation originating from any given particle arriving at the sensitive region of the detector. This probability is made up of three factors.

1. The solid angle subtended by the detector, with the particle as the vertex.

2. The average absorption factor which prevails for the radiation lying in the given solid angle.

3. The efficiency of the detector for radiation coming in from the direction of the particle.

The weighing factor falls off continuously with distance away from the detector, nowhere falling abruptly to zero. At considerable distances, however, the weighing factor is so close to zero that the neglect of all matter beyond the rather thick shell will cause a negligible influence on the measurement.

Fearon[6] has calculated the relative physical size of samples in gamma ray logging and coring and compared them in the table below. The two sets of samples have equal lengths.

Table (8)

Radioelement Predominately Responsible for Radiation	Wt. of Log Sample	Wt. of 3" Core Sample
Radium and series	370 lbs.	25 lbs.
Thorium and series	560 lbs.	25 lbs.
Potassium 40	160 lbs.	25 lbs.

Sampling of the Neutron Curve

The sampling of the Neutron Curve cannot be quantitatively treated as was the Gamma Ray Curve, because of the lack of information on the range of neutrons in the various rock substances. However, the available data on neutron ranges as well as that on the absorption of gamma rays of the hardness of those comprising the I_1 component tends to confirm the belief that the Neutron Curve sample is at least as large as that of the Gamma Ray Curve.

In neutron logging as in gamma ray logging the sampling process differs from that of coring and the weighing factor also falls off with distance from the instrument.

The manner in which the weighting factor varies in space differs markedly in the two cases making it a matter of particular interest to consider the shape of the sample observed.

Fearon[7] has also calculated the shape of the sample in neutron logging by first making the following definitions:

A. The weighting factor in neutron well logging is the rate of change in detecting secondary radiation (I_1) intensity with respect to molar density of representative substance at the point for which the weighting factor is determined.

B. The relative weighting factor is the ratio of the weighting factor at any given place to the value it would have at its minimum between source and detector, on a line joining them, if the space between source and detector were filled with material of the same nature as the surrounding rock.

C. The sample is the quantity of matter contained in a surface on which the relative weighting factor is $1/e$.

The mathematical development of such surfaces is quite complicated and therefore only the shape of some simple examples will be considered.

Where both the neutron flux and the induced gamma ray flux have large penetrating power and neither is absorbed appreciably upon passing through the rock a distance equal to the space between the source and the detector, the log sample inside a surface of relative weighting factor, is the solid of revolution of which a section through the axis of rotation has the form:

$$r^3 = 4a^3\cos\theta - 2a^3 \qquad (7)$$

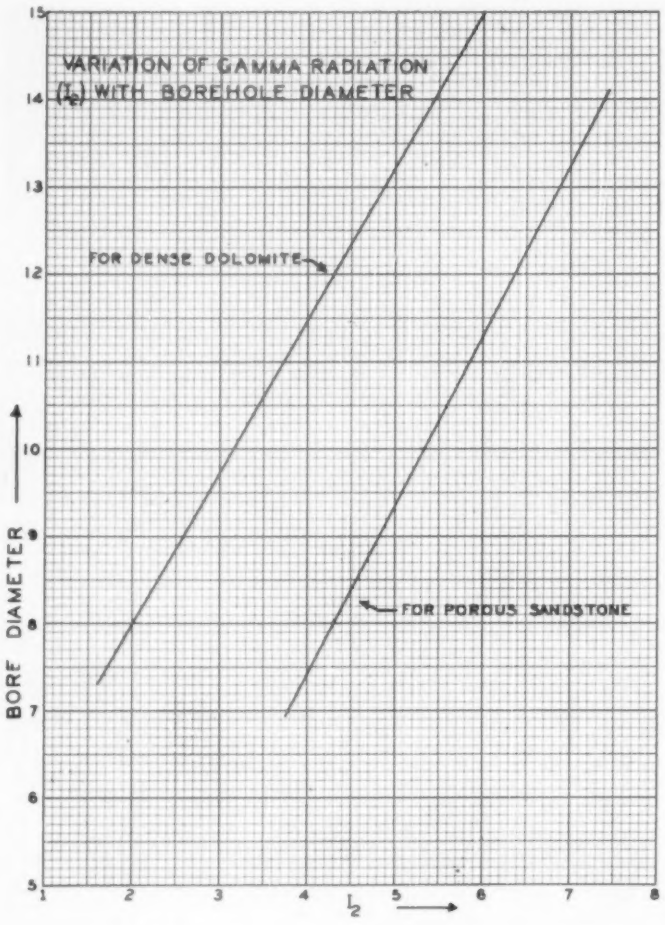
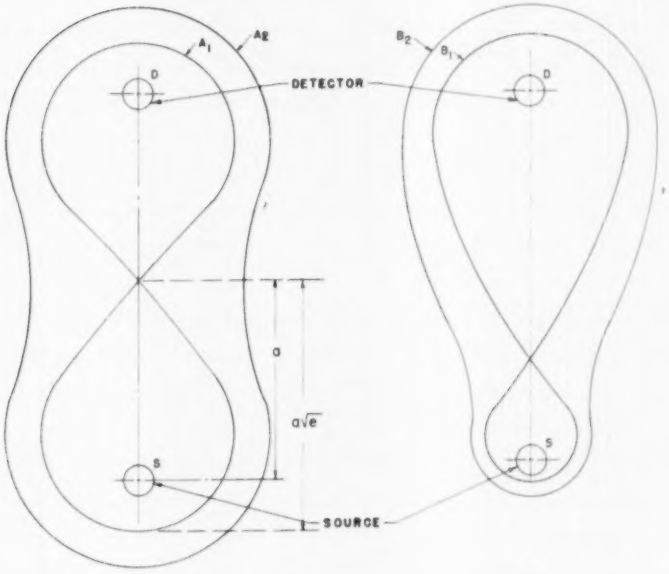


FIG. 6 — EFFECT OF BOREHOLE DIAMETER ON THE SCATTERED GAMMA RADIATION (I_2)

This equation is illustrated by the inner curve of Fig. 7a. The case where the emitted radiation is more penetrating than that detected is shown by the inner curve of Fig. 7b. The outer curves represent the pattern for a fractional weighting factor. The outer curve in Fig. 7b represents the zone sample by the existing commercial equipment.

In any case, however, when it is recalled to mind that μ_i is the determining quantity, it will be apparent that the "core" sampled by the neutron log would be a reasonable approximation to a cylinder the radius of which would vary with μ_i, and therefore the radius would vary with the activity indicated by the neutron curve, i.e., the greater the activity encountered the greater the radius of the core sampled.

The log sample differs therefore, in several ways from samples secured within the borehole. In the first place the core obviously samples the zone within the radius of the borehole while the log samples the zone outside the borehole. This difference should be kept in mind when comparing core data with the neutron log for those formations where the hetergeneity of the porosity distribution is pronounced such as is the case with most of the limestones and dolomites, e.g., the Ellenburger in particular. In the second place, the log sample is much larger than the core sample. The core sample therefore cannot be expected to agree exactly with the log sample, for the types of formations enumerated and it is highly probable that the porosities calculated from the log may be more valuable than those obtained from cores for estimating net pay and reserves.



A_1 AND B_1 REPRESENT SURFACES CORRESPONDING TO WEIGHTING FACTOR OF ONE.
A_2 AND B_2 ARE SURFACES CORRESPONDING TO FRACTIONAL WEIGHTING FACTORS.
IN FIGURE A IT IS ASSUMED THAT THE EMITTED AND DETECTED RADIATIONS HAVE A VERY SMALL ABSORBTION IN PASSING A DISTANCE SD THROUGH THE ENVIRONMENTAL SUBSTANCE.
IN FIGURE B THE DETECTED RADIATION IS APPRECIABLY ABSORBED.

FIG. 7 — THEORETICAL SHAPE OF THE NEUTRON CURVE SAMPLE

METHODS OF QUANTITATIVE INTERPRETATION

Limited to Liquid Filled Porosities

The methods of interpretation presented in this paper apply only to liquid filled porosities. Unfortunately, the influences of saturation on the Neutron Curve are too complex to be discussed in this paper. The authors hope to be able to treat this subject in another paper, shortly.

General Discussion

The foregoing discussion of the basic theories has shown that there is a physical basis for the assumption that the Neutron Curve might be calibrated in terms of porosity. When this can be done, a powerful tool will be available for determining the porosity of reservoir rocks which will be simpler to apply to evaluation and other reservoir problems than similar data obtained from cores because of the better sampling of the neutron logging process.

Before this can be done a fairly complete background of information on the behavior of the variables C and μ_i must be compiled. With this information together with the hole sizes, the casing record, and knowledge of the chemical nature of the lithology, it should be possible to determine the porosity of the zone sampled by an absolute method.

However, the information on the variables C and μ_i is not available and therefore we must rely on relative methods which really offer almost all the advantages of the absolute method except those of flexibility and a wide range of applicability.

If the well completion procedures are the same (all wells were drilled to same bore diameter and have the same casing program) and the rock matrix is the same, the variables C and μ_i will reflect only porosity changes and the component I_i will be almost constant; hence the Neutron Curve will reflect mainly porosity changes. Therefore, if such a well is cored and logged, the relationship between the porosity of the cores and the log deflections can be determined, and this relationship can then be applied quantitatively to neutron logs of the other wells in the field in

order to determine the porosities of their portion of the pay without determining the factors C and μ_c.

Relative Methods of Quantitative Interpretation

To determine the relationship between the deflections of a particular Neutron Curve and porosity it is necessary that sufficient core data be available in order that a wide range of porosity values will be at hand, and when these porosity values are compared with the Neutron Curve it must be kept in mind that there may be slight discrepancies in depth between the core log and the radioactivity log and the comparison must be made therefore with the core porosity log properly correlated as to depth with the radioactivity log. This is the first and one of the most important steps in making the interpretation.

The second important step is to establish the proper reference line for the Neutron Curve because it has no absolute zero.

Reference Lines

There are three possible choices for reference lines discussed in this paper. First there is the combination of a shale line and a dense limestone or anhydrite line; second, there is the shale line alone; and third, there is the dense limestone or anhydrite line alone.

These three possibilities give the interpretation method a wider field of application than would be possible with just one reference line, since a single standard reference line would not be applicable to all lithologies or to all types of completions.

Combination of Shale and Dense Limestone or Anhydrite Reference Lines

Where the formations are consistent and it is possible to log a thick shale and a limestone containing a dense zone or an anhydrite streak through the same number of casing strings or in open hole the difference between the Neutron Curve deflection of shale and that of the dense zone is considered to be the total neutron deflection and the deflections of the log are then converted to percentages of this total deflec-

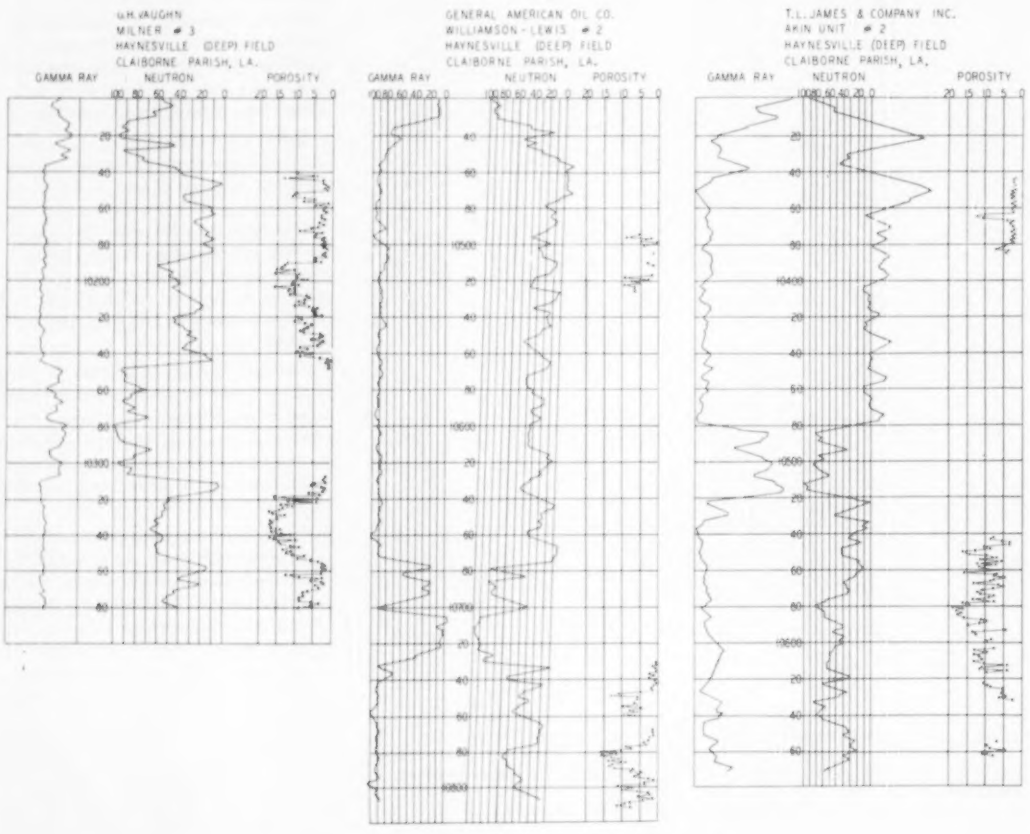


FIG. 8 — SMACKOVER LIMESTONE LOGS AND POROSITIES

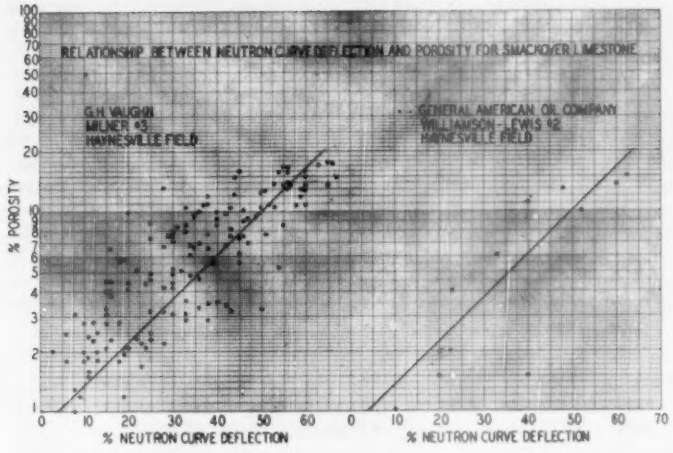


FIG. 9 — RELATIONSHIP BETWEEN NEUTRON CURVE DEFLECTIONS AND POROSITY FOR SMACKOVER LIMESTONE

tion. These percentages are then plotted against the porosities. Shale is assigned a value of 100 and the dense material a value of zero and the intervening distance is divided into 10 equal parts in order to provide a scale. This method will be referred to hereafter as the per cent of neutron deflection method or the percentage method.

This method has an important advantage over the others in that it is possible to compare curves run on different sensitivities without correcting for the sensitivity differences.

However the application of this method of choosing reference lines must be limited to those fields which exhibit consistent uniform shale lines and consistent dense zones. The hole diameter should be uniform and the shale there-

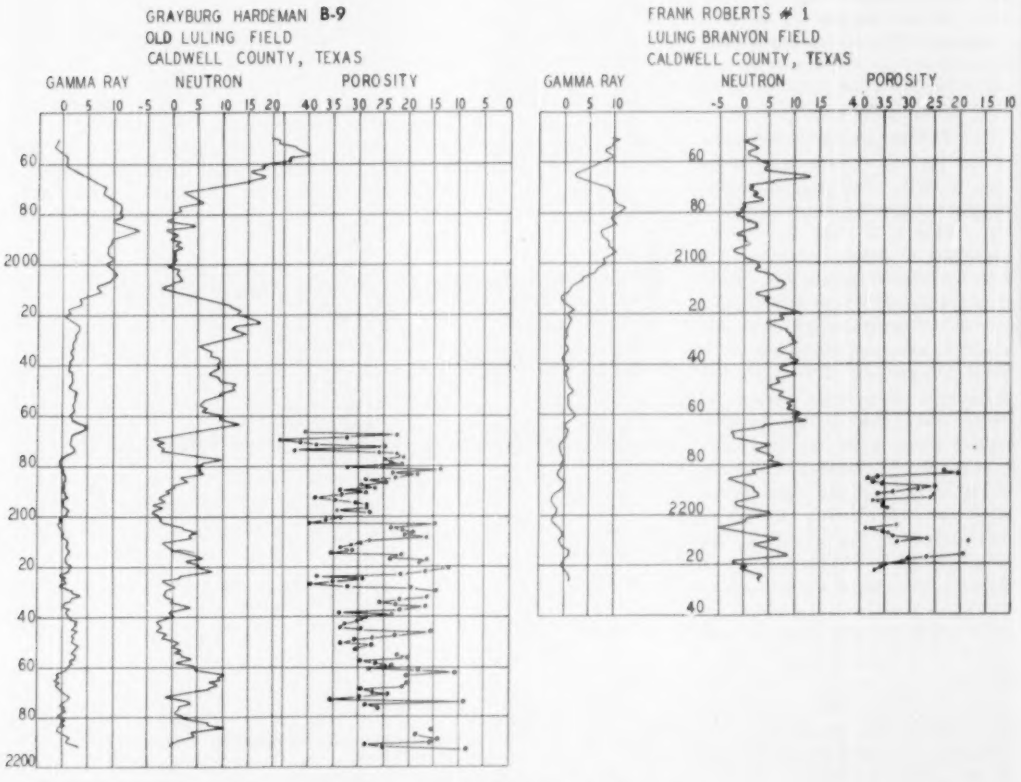


FIG. 10 — LULING — EDWARDS LOGS AND POROSITIES

fore should be stable in the drilling fluid and no sloughing should occur as this would result in enlarged bore diameters where the I_1 component of the log might be large enough to introduce error into the calibration curve.

The success of the method depends on the maintenance of the I_1 component at a very low level. If there is doubt as to the constancy of the bore diameter through the reference zones and the zone to be analyzed a caliper survey should be run. Usually if the zones to be studied all lie close to the bottom of the well, the diameter will be true to bit size and uniform and the value of the I_1 component therefore will be small and will vary only slightly from well to well.

Either dense limestone or anhydrite can be used for the other reference line. If an anhydrite zone is used it should extend throughout the field for an anhydrite reference line should not be used interchangeably with a dense limestone reference because the factor C apparently differs for anhydrite and limestone and the variation in the reference line will cause distortion of the calibration curve.

Fig. 8 shows an example of this method applied to three radioactivity logs of wells penetrating the oolitic Smackover limestone. The average shale line chosen is constant in all three wells, and is uniform throughout the field. It is obvious that the data derived from this group of logs is applicable only in this particular field, and only where the same casing program is followed. The per cent of Neutron Curve deflection is plotted as the abscissa and the per cent porosity as the ordinate on semilog graph paper and the points scattered along a straight line as shown in Fig. 9. Although the points do not all conform closely, they will fall in such a fashion that a straight line drawn through them will represent an average of the neutron derived porosity. This curve may then be applied to any other well in the field which has been completed in a similar manner, with a degree of accuracy which is limited by the quality of the sampling process, and the statistical and instrumental errors involved. (Unfortunately time and space do not permit a discussion of these latter factors in this paper).

Shale as the Reference Line

If a dense zone is not present under the same hole and casing conditions as the zone to be investigated but a shale is present under these conditions, the shale may be used as the reference line and the Neutron Curve deflections are then measured from this line.

Washing out of the shale may introduce the same errors in this method due to the greater I_1 component associated with larger hole diameters as it did in the case of the percentage method and it is therefore essential that the shale be stable and the borehole diameter true to bit size.

The Neutron Curve deflections, measured from the shale line are plotted against the porosities of the known well. The neutron derived porosities for the unknown wells may then be determined by directly comparing the Neutron Curve deflections from the unknown wells with the calibration curve, if the log sensitivities are the same.

If the log of the unknown well was run on a different sensitivity from that

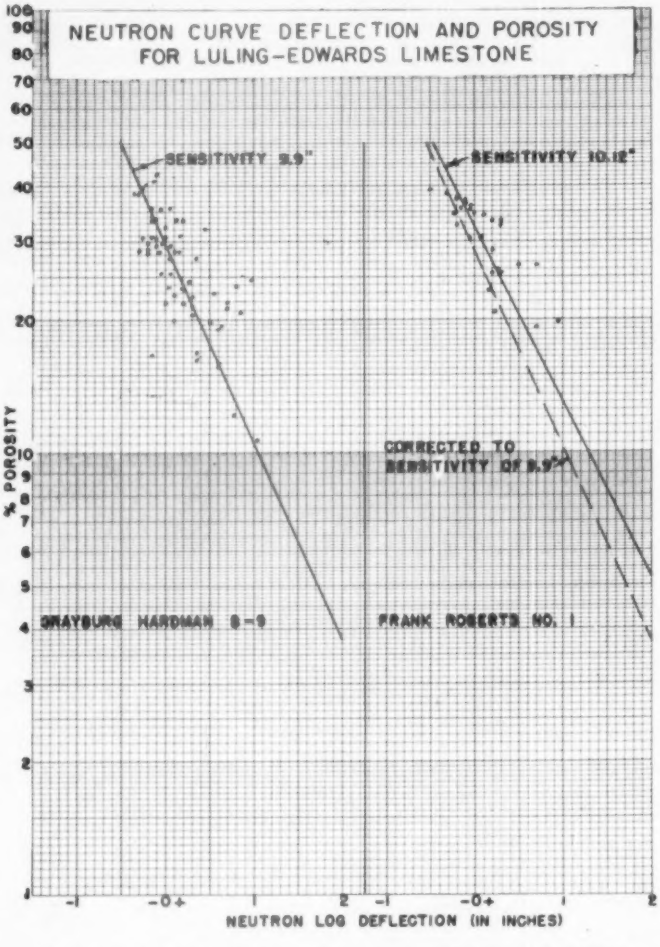


FIG. 11 — RELATIONSHIP BETWEEN NEUTRON CURVE DEFLECTIONS AND POROSITY FOR LULING — EDWARDS LIMESTONE

of the known well, the deflection of the unknown well must be corrected to correspond to the sensitivity of the log of the known well. The corrected curve deflection may then be compared with the calibration chart and the neutron derived porosity determined.

The correction for the change in sensitivities may be done as follows:

$$D_2 = \frac{S_2 D_1}{S_1}$$

Where:

D_2 is the corrected Neutron Curve deflection for the unknown well

D_1 is the deflection from the curve of the unknown well

S_1 = sensitivity of the curve of the unknown well

S_2 = sensitivity of the curve of the known well.

This correction has been made in this manner because it is believed that the reader will find it more convenient to convert the deflections of the unknown curve to the scale of the known curve and then compare these converted deflections to the calibration curve. However, it is easily possible to convert the calibration curve to the sensitivity of the unknown Neutron Curve. This may be done by allowing D_1 to represent some point on the cold calibration curve. D_2 will therefore represent the same point on the new curve.

This method of using a base line is illustrated by Fig. 10 showing two logs of Edwards limestone correlated with porosity data obtained from diamond cores. Fig. 11 shows the calibration curve resulting from plotting the neutron deflections measured from the shale line against the per cent porosities determined from core analysis.

Dense Zones as References

In the method first described, dense limestone was used as a reference line in that the difference on the Neutron Curve deflection in a shale zone and in a dense zone was used. It is quite frequently the case that casing programs require casing off shale and setting the casing shoe in the upper portion of the productive limestone or dolomite. In these cases a comparison with the cased off shale is not practical, and a dense zone within the limestone may be selected to be used as the reference line for the log. In this method the Neutron Curve deflection is measured from this reference and these deflections are plotted against the porosities of the base or known well. The neutron derived porosity for an unknown well in the field may then be determined by directly comparing the Neutron Curve deflection from the log of the unknown well with the calibration chart obtained on the known well, provided the log sensitivities are the same.

If the log of the unknown well was run on a different sensitivity from that of the known well, the deflections of the unknown well must be corrected to correspond to the sensitivity of the known well as has been described in the case of the shale line.

Fig. 15 illustrates the application of a dense zone as a reference line for the Neutron Curve.

Selection of the Most Applicable Method

Each of the described methods of using reference lines can provide a means of determining neutron derived porosities for a given zone by the application of the calibration curve determined for a base or known well to the neutron logs of the unknown wells. Due to the variations from area to area in the casing programs, borehole conditions, and lithology, the applicable method is that most commensurate with those conditions.

SPECIFIC APPLICATIONS

Smackover Limestone

To illustrate the technique used in the application of quantitative interpretation methods, widely differing

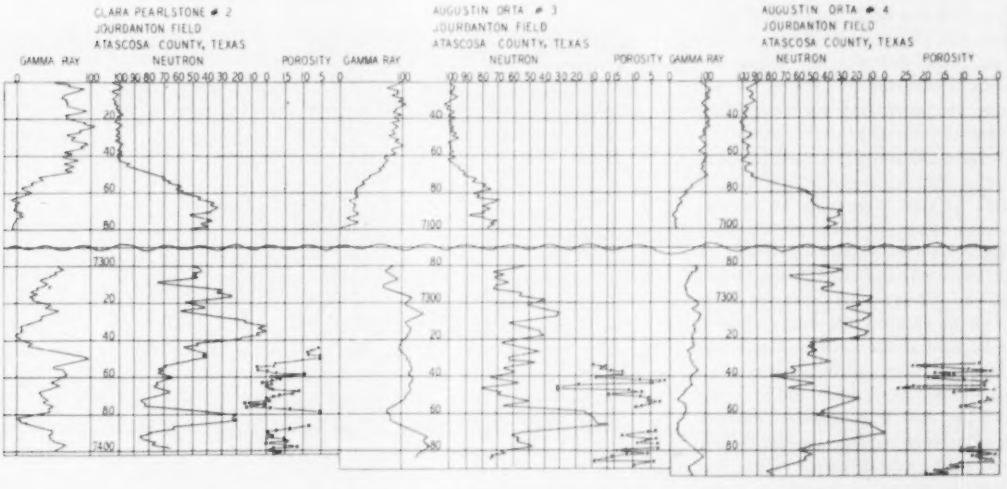


FIG. 12 — JOURDANTON — EDWARDS LOGS AND POROSITIES

fields, both geologically, lithologically, and geographically have been selected as examples. Fig. 8 shows three logs of wells located in the Haynesville (Deep) Field, Claiborne Parish, La., which have penetrated the Smackover limestone. The logs are aligned so that the correlation of the shales and limestone beds can be observed in order to illustrate the similarity of character of all three logs. The per cent neutron deflection method of porosity interpretation was chosen for this field because:

1. The hole was entirely cased.

2. Shales are present and are both consistent and correlative.

3. Dense limestone is scattered throughout the A and B Smackover zones.

Shale lines were determined by averaging the peaks of shale at the left of the log, the slope of which is found by extending the line several hundred feet up the log. A value of one hundred per cent is assigned this line, since it represents the lowest value on the log, and shows the greatest influence of hydrogen on the I_2 component. The greatest deflection within the Smackover was chosen as the dense limstone or zero point. The distance from zero to one hundred per cent was divided into parts of ten, with proportional dividers, and lines therefrom were extended over the zone of interest parallel to the shale line.

Due to excessive bottom hole temperatures the log of the General American Oil Company's Williamson-Lewis No. 2 has drifted to the right. This drift is corrected by drawing the zero line and the proportional division lines parallel to the slope of the shale line.

The curve is now prepared for correlation with the available core data. In this instance these data are already plotted and correlated on the same depth scale as the Neutron Curve. Correlations will vary slightly where coring is not continuous, and depth corrections must be checked for each individual core. A convenient method of recording data is to correct all depths to the Neutron Curve depth scale and to record the per cent neutron curve deflection directly from the log, opposite the corresponding porosity value. These data may be plotted on coordinate paper, and a curve drawn through the average of the points, but difficulty will be encountered in extending the curve past the limits of the available data, therefore semilog graph paper was selected for this purpose and reliance was placed on the behavior of the I_2 component as shown in Fig. 5.

Fig. 9 is the graph of the data obtained from the Milner No. 3 and the Williamson Lewis No. 2. It will be noted that a large dispersion of points occurs on either side of the average curve. However, dispersion is to be expected from the comparison of the neutron log deflections to the porosities due to the differences in sampling and the heterogeneity of the porosity distribution. The core analysis sample is obtained from a small plug representing only a small portion of one foot of core sample while the neutron sample would be very much larger. A smoother curve may be obtained by averaging three core samples, but no real improvement would be gained because the averaging is accomplished by using the same core samples as before.

When established for a field this curve may be applied to the log of an unknown well, and the neutron derived porosity determined.

Luling — Edwards Limestone

Two fields producing from the dolomitic Edwards Limestone of Southwest Texas have been selected as illustrations. This formation differs from the relatively homogeneous oolitic Smackover limestone in that the heterogeneity of the distribution of porosity in this dolomitic limestone is much more pronounced. Horizontal correlation in this type of material is poorer, and it will characteristically extend over only a few inches of sample. For this reason the two methods of sampling used in coring and well logging will cause wide dispersion of data.

Fig. 10 shows two logs of the Edwards limestone which were cored with a diamond core bit. Throughout the entire zone, high porosity is present, and no reliable dense material is available for use as a log reference line. The Grayson shale shown at the top of the log is quite extensive and constant throughout the area, and serves as an excellent marker. For this reason it was chosen as the relative log reference line.

The log reference line was established by drawing a line through the

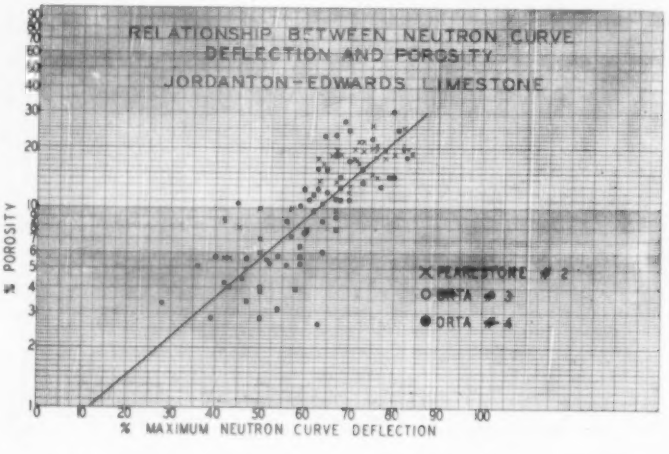

RELATIONSHIP BETWEEN NEUTRON CURVE DEFLECTION AND POROSITY
JORDANTON-EDWARDS LIMESTONE
% POROSITY
% MAXIMUM NEUTRON CURVE DEFLECTION
X PEARSTONE # 2
O DATA # 3
● DATA # 4

FIG. 13 — RELATIONSHIP BETWEEN NEUTRON CURVE DEFLECTIONS AND POROSITY FOR JOURDANTON — EDWARDS LIMESTONE

average of the shale peaks at the left of the log. A scale in inches is used to determine the changes in deflection from the reference line. In this example the porosities of the dolomite are high and the neutron deflection extends to the left of the reference line. To measure these intensity changes a negative scale in inches is established. The neutron curve is then correlated with a plot of the porosity, and the neutron log deflections from zero determined for the corresponding porosity. These data are plotted on semilog graph paper with the neutron log deflections as the abscissa and per cent porosity the ordinate, and an average line drawn through the points. The neutron derived porosity calibration curve is now established for this log. Fig. 11 shows the neutron derived porosity calibrations for the Grayburg Hardeman B-9 and the Frank Roberts No. 1.

To illustrate the procedure involved in correcting the Neutron Curve deflection for a given sensitivity to a different sensitivity, a deflection of the Frank Roberts No. 1, is two inches, and the curve was run on a sensitivity of 10.12 inches. This deflection may be corrected to apply to the log of the Hardeman B-9 which was run on a sensitivity of 9.9 inches, as follows:

$$D_2 = \frac{S_2 \times D_1}{S_1}$$

$$D_2 = \frac{9.9 \times 2}{10.12}$$

$$D_2 = 1.96 \text{ in.}$$

The corrected log deflection now may be applied to the calibration curve of Hardeman B-9. Since the Frank Roberts No. 1 was cored it is possible to check the accuracy of the neutron derived porosities with the porosities determined from cores.

Fig. 11, however, shows the derived porosity curve for the Hardeman B-9 corrected to the sensitivity of the Frank Roberts No. 1. This was done by taking points off the Hardeman B-9 calibration curve and substituting them in the above equation for D_1. Values of D_2 were then plotted against the porosity to obtain the new calibration curve.

Jourdanton — Edwards Limestone

Another example of Edwards limestone quantitative interpretation is shown in Fig. 12. In this example three logs are shown with corresponding core dnta. The neutron percentage method of quantitative interpretation was chosen for the Jourdanton Field because of the presence of the Grayson shale and an extensive anhydrite bed located within the productive Edwards. The procedure involved in this interpretation is identical with the method used for Fig. 8, with the exception of the reference line utilized. In the Jourdan-

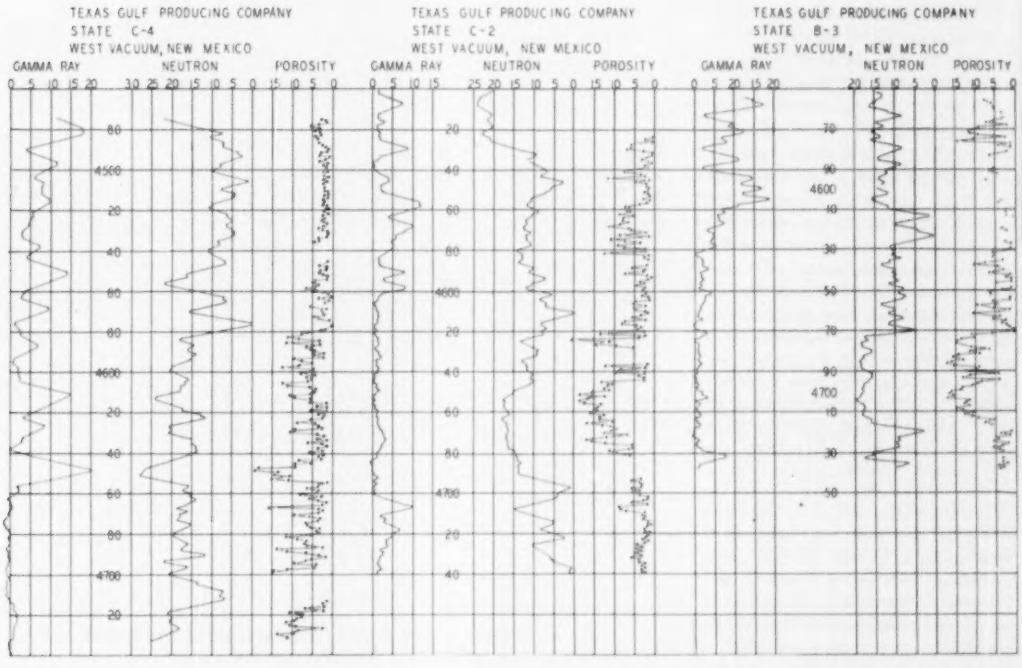


FIG. 14 — WEST VACUUM DOLOMITE LOGS AND POROSITIES

ton Field the anhydrite bed was chosen as the log reference instead of the dense limestone. Fig. 13 shows the combined plot of the per cent neutron curve deflection versus per cent porosity. No further correction is required for application of this neutron derived porosity calibration curve to logs of uncored wells in this field provided the same markers are available in each well.

Permian Dolomites

Permian dolomites of West Texas are highly hetergeneous and are quite often contaminated by silty material. The heterogeneity of these formations cause a wide dispersion of porosity values over extremely short intervals and samples taken from the borehole as cores, are highly dissimilar to the sampling of the Neutron Curve outside the borehole. For this reason neutron porosity curves determined from logs of this area exhibit a greater dispersion of points. A further complication is introduced by the presence of silty material which introduces deflections in the Neutron Curve similar to those due to porosity by the effect on the I_1 component of the chemically combined hydrogen, characteristic of silty material. In zones of this type the normal procedure must be varied slightly to determine the effect of the silty material on the neutron porosity curve. The procedure followed in Fig. 16 accounts for and corrects for the effect of the silty material. Three logs shown are of wells located in the West Vacuum field, New Mexico, which have penetrated the San Andreas formation, a silty dolomite. The State C-2 was chosen as the base well for determining the neutron porosity curve. The highest deflection represents dolomite of very low porosity and is used as the log reference. A scale in inches was established by tracing the log on rectangular coordinate paper to show the intensity changes from zero. The neutron derived porosity calibration curve was determined by utilizing only porosity data obtained from a zone shown by the low intensity of the Gamma Ray log to be silt free. The points for this curve is shown by Fig. 15 and it represents the neutron derived porosity calibration curve for this particular log which was run on a sensitivity of 2.34 in. The data for wells C-4 and B-3 were also determined in the same fashion and their neutron derived porosity calibration curves plotted. To illustrate the application of the base neutron derived porosity calibration curve to uncored wells the State C-2 neutron porosity curve has been corrected to the logs of differing sensitivity of the State C-4 and B-3 and is shown by the broken line on each respective graph.

Correction for Silty Material

Correction for the effect of silty material is determined first by drawing an average of the lowest intensity values on the Gamma Ray Curve and establishing a scale in inches to determine the changes in its deflection. The Radioactivity log of the State C-4 was chosen for this determination because of the presence of much silty dolomite which had been cored. By referring the Neutron Curve deflections to the derived porosity calibration curve an apparent derived porosity is found and by subtracting from it the porosity of the core analysis the derived porosity subtractive component is found. The Gamma Ray Curve deflections are then plotted

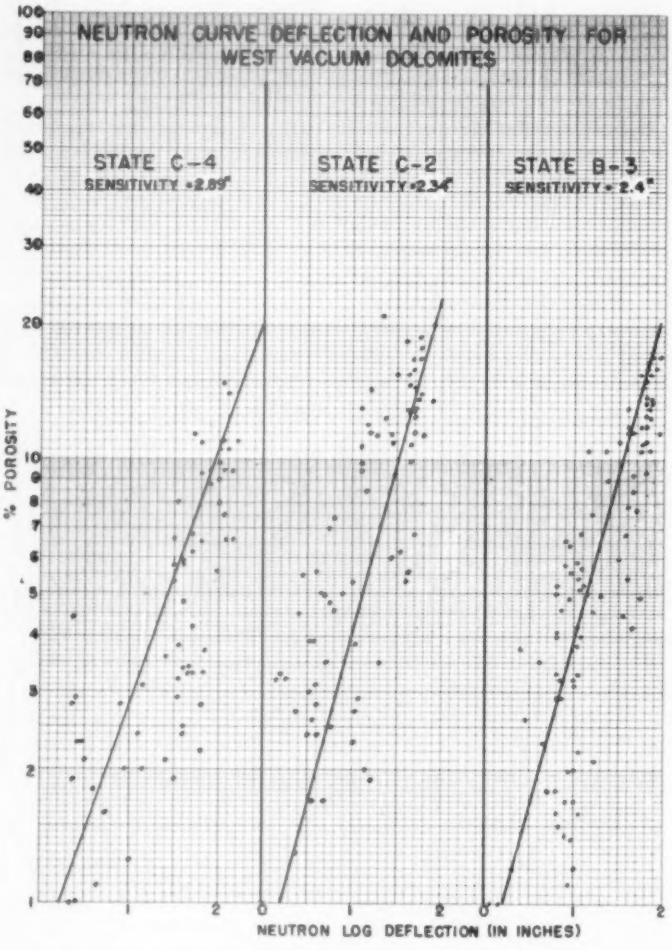


FIG. 15 — RELATIONSHIP BETWEEN NEUTRON CURVE DEFLECTIONS AND POROSITY FOR WEST VACUUM DOLOMITES

as the abscissae and the subtractive components are plotted as the ordinates on semilog graph paper and an average line is drawn through these points to provide a silt correction curve. The silt correction curve for the State C-4 is shown in Fig. 16, and has been corrected proportionally to the sensities of the Gamma Ray Curves of the State C-2 and State B-3. This procedure is the same as that shown by the formula previously shown for the correction of Neutron Curve deflections to a curve of different sensitivity. The complete determination of the neutron derived porosity may be expressed in the following formula:

$$P_n = P_{na} - P_s$$

Where:

P_n is the corrected neutron derived porosity.

P_{na} is the apparent neutron derived porosity read from the neutron deflection calibration curve.

P_s is the porosity difference caused by the decrease in intensity of the Neutron Curve due to the presence of hydrogen in silty material. This value is obtained from the silt correction curve, by referring to it the deflection of the Gamma Ray Curve. It is apparent that the dispersion of points on the silt correction curve should be extremely high due to the chemical heterogeneity of the dolomite plus the heterogeneity of the distribution of silty material plus the heterogeneity of the distribution of porosity.

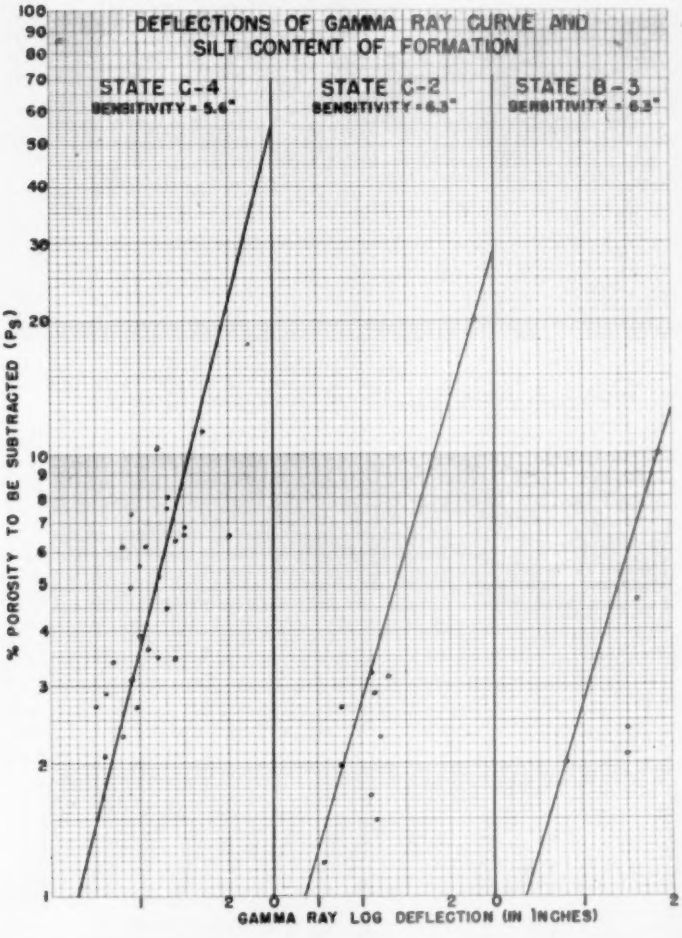

DEFLECTIONS OF GAMMA RAY CURVE AND SILT CONTENT OF FORMATION
STATE C-4
SENSITIVITY = 5.6"
STATE C-2
SENSITIVITY = 6.3"
STATE B-3
SENSITIVITY = 6.3"
% POROSITY TO BE SUBTRACTED (Ps)
GAMMA RAY LOG DEFLECTION (IN INCHES)

FIG. 16 — RELATIONSHIP BETWEEN GAMMA RAY CURVE DEFLECTIONS AND SILT CONTENT

SUMMARY AND CONCLUSIONS

The theoretical basis of radioactivity logging has been briefly discussed and the physical processes determining the logs have been described. The neutron log depends mainly on two variables, C a "chemical" factor which varies with the chemical composition of the sample on the surrounding rock and μ, the absorption coefficient for the neutron flux in the surrounding rock. μ is largely a function of the hydrogen content of the rock and therefore is most strongly affected by fluid in the porosity.

The sampling of radioactivity curves is known to penetrate radially much deeper into the formation than other methods of sampling such as cores, reverse cuttings, and sidewall samples resulting in a much larger sample than those methods. The radioactivity curve sampling should therefore be superior for those formations exhibiting an extremely heterogeneous porosity distribution.

Relative methods of quantitative interpretation of radioactivity logs have been described which offer a means by which a neutron derived porosity can be determined for wells that have not been cored, by establishing a derived porosity curve from a selected base well, the data being applicable within limits of certain lithological and casing conditions. Versatility is obtained by utilizing the log reference points most applicable to the area. Homogeneous formations like the oolitic limestones show less dispersion of points plotted from these data, while heterogeneous formations such as Edwards limestone and dolomite and Permian dolomites show much greater dispersion.

While the methods presented in this paper offer the advantages of universal application to radioactivity logs, it is

recognized that an absolute reference would offer greater accuracy to quantitative interpretation, and would increase the applicability of quantitative methods to data throughout the oil producing territories and remove the limitations imposed by changes in lithology and casing programs on relative quantitative interpretation methods. This development, however, still remains for the future.

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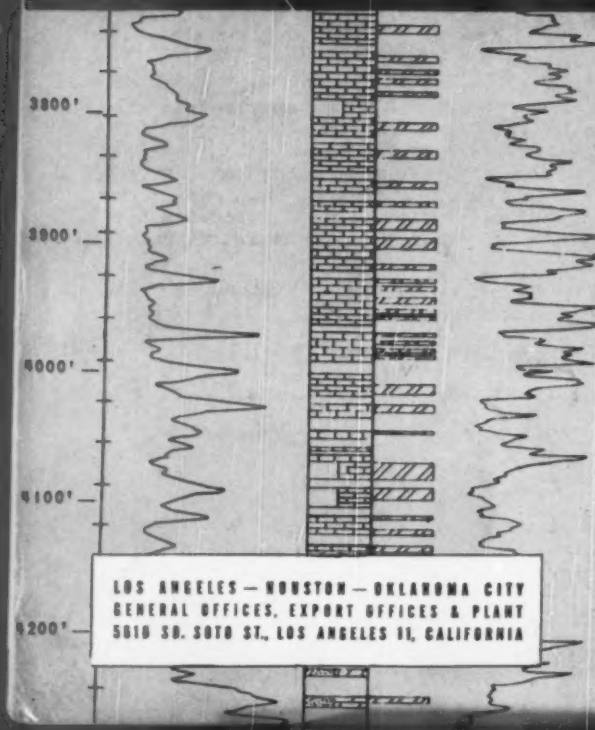

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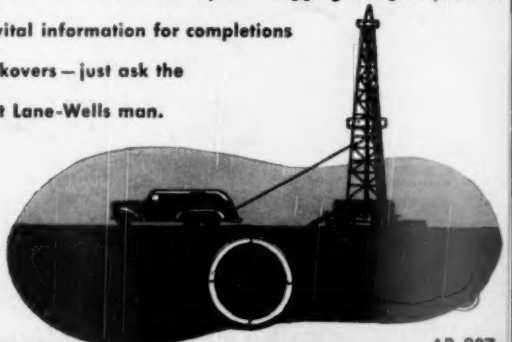

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